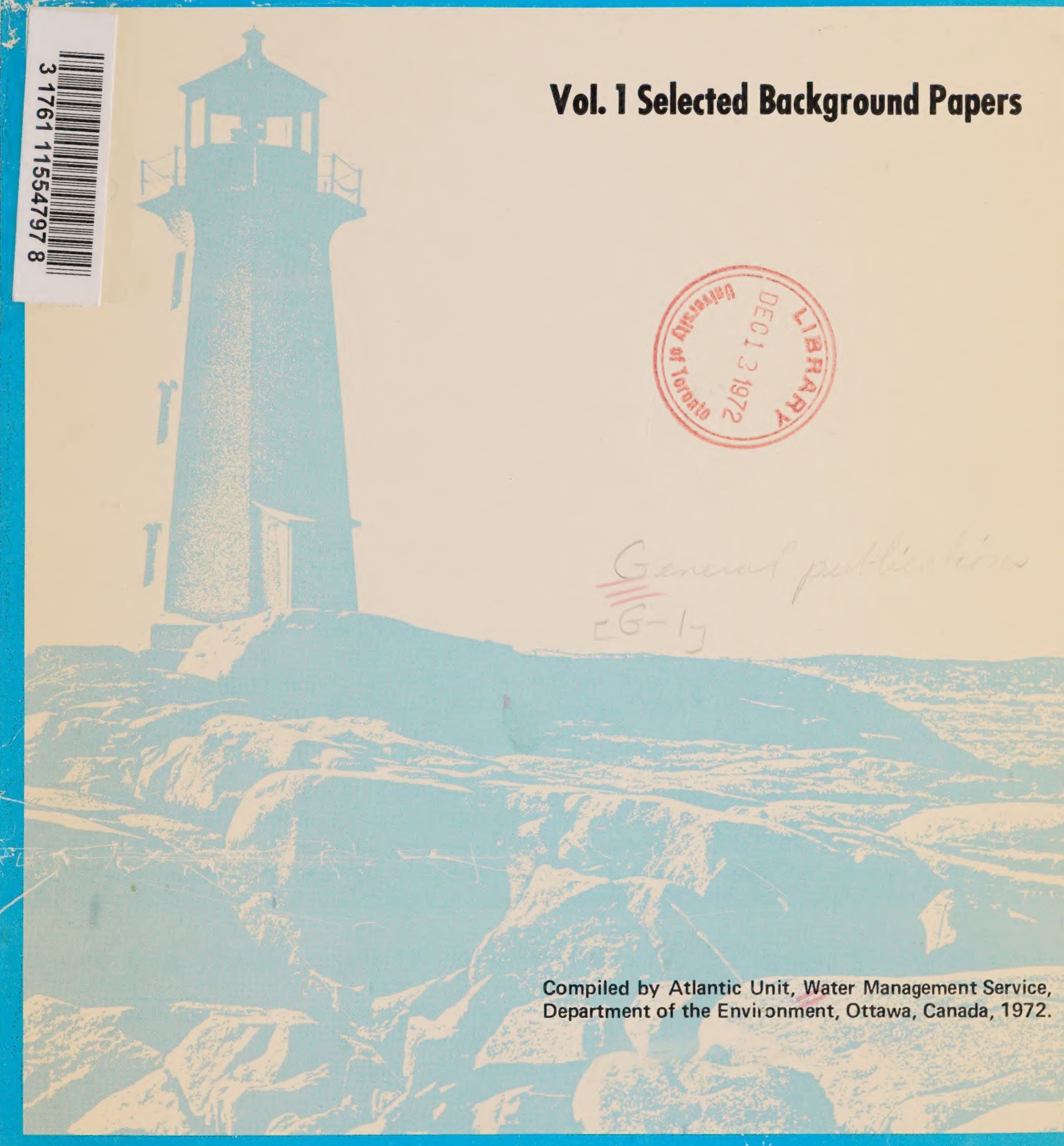
Environment Canada — Environnement Canada

Coastal Zone

Proceedings of a Seminar held at Bedford Institute of Oceanography, Dartmouth, Nova Scotia, March 1972.



Vol. 1 Selected Background Papers

Compiled by Atlantic Unit, Water Management Service,
Department of the Environment, Ottawa, Canada, 1972.

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FOREWORD

An important part of the Canadian environment is the narrow strip of land and water around our coasts. A resource of the first order, this coastal zone is experiencing increasing pressures from many uses. It is capable of yielding a continuing stream of aesthetic, recreational, and commercial benefits - providing the harmful effects of many uses are reduced or prevented. To secure these future benefits society must recognize and understand the dynamic nature of the coastal environment and the vulnerability of its intrinsic qualities. At present, the growing pace and scale of development, the undesirable acceleration of natural processes, and the irrevocable disturbance of valuable habitats are all cause for concern.

The papers brought together in this volume provide an overview of some of the many elements and processes that impart to the coast its special character. They also indicate some of the increasing demands made upon the coast and the problems these give rise to.

These papers were first presented at a Departmental Seminar on the Coastal Zone sponsored by the Water Management Service of Environment Canada. Besides describing important coastal conditions and circumstances they illustrate the Department's interests in a wide range of coastal land, water, and air topics.

In making this volume of papers available to a wider public we hope that it will serve to stimulate greater interest in the coastal zone and more intensive study of the development and planning problems posed by the coastal environment.

L. Edgeworth

L. Edgeworth,
Assistant Deputy Minister,
Water Management Service.

CONTENTS

*Denotes oral presentations.

Water

SEA-ICE AS AN ENVIRONMENTAL FACTOR

W.A. Black[1]

The extent to which sea-ice limits man's activities in the St. Lawrence region is highly variable. To live with ice for many months, year by year, presents problems for the population of towns and villages that border the Gulf coast. Icefields impose an isolation on the region; towns and villages become locked up in the estuaries; the icefields impose a strain on or prohibit waterborne transport; besides, to live by the cold, silent, white sea of ice for long periods of time must be psychologically depressing. In addition, there is the constant danger of damage by ice to ships and shore installations, of the deterioration of the beach and shoreline caused by the grinding action of drifting ice. The Gulf icefields, together with shortened days and rough weather, impose a severe restriction on fishing activities -- a cessation of fishing activities of upwards of six months for the inshore fishermen; moreover, fish processing plants in the region operate only during the open season. Present recreation development in the Gulf region is mainly limited to the summer months. Both recreation and fisheries' development are seasonal and find it difficult to attract capital investment for development purposes. Undoubtedly, the economic effects imposed by ice are severe and it is likely that ice has been an important factor contributing to the retarded socio-economic development of the region bordering the Gulf of St. Lawrence and to the difficult task of devising a successful industrial-mix for the region.

To appreciate ice as an environmental factor it is important, first of all, to understand certain characteristics of ice behaviour in the Gulf region such as: its regional distribution, ice-type composition, ice drift, the tendencies for certain areas to have heavy ice congestion and, vice versa, monthly and annual changes in the ice cover, and the growth and depletion of the ice cover. These characteristics, in varying degrees, have a bearing on human activities. Very little research has been done on sea-ice as an environmental factor affecting human activities in the Gulf region; a fully definitive work has yet to be written. This brief study is concerned with the critical relationships between the ice-congested waters of Northumberland Strait and the development of effective transportation and communication between Prince Edward Island and the Mainland; it is, in effect, on historical perspective of the navigational use of ice-congested waters.

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1 Lands Directorate, Lands, Forest and Wildlife Service, Department of the Environment.

This study is divided into several parts:

Characteristics of the Sea-Ice Distribution in the Gulf of St. Lawrence
The Conquest of the Icefields of Northumberland Strait
Conclusion

Characteristics of the Sea-Ice Distribution in the Gulf of St. Lawrence

The growth of sea-ice is an important element of the marine environment in this region.[1] From August onward, with declining net radiation, surface water cools and when it reaches the temperature of maximum density, 39.2°F., it sinks. As temperatures continue to fall and heat energy in the water is lost to the air, surface seawater begins to freeze when the temperature reaches 29°F. With sustained freezing temperatures, the ice continues to thicken at the base, along the interface between ice and water. In addition to the reduced net radiation during the winter months, the formation, thickness, and extent of the ice-cover is greatly affected by the dominance of arctic continental air masses, the persistence and strength of the W-NW-N winds, and the frequency of storms crossing the Gulf region. These, together with tides, give rise to vertical mixing, to thermal stratification and to the loss of heat energy from open water. The Coriolis force, which causes water, including the drifting ice, to deflect to the right or south side in the northern hemisphere, is an important factor in both ice-drift and the upwelling processes. Thus the prevailing winds, in conjuction with the Coriolis force, contribute to the striking phenomena, even in the severe weather of mid-winter, of open water bordering the north shore of the Gulf and other down-wind coasts; they contribute to the prevailing drift of the ice across the Gulf, and to the massive buildup of ice against on-wind shores such as the Gaspé coast and in the catchment basin of the southern Gulf. Inflows of fresh water from interior rivers reduce seawater salinity, particularly in the shallow protected bays and estuaries of the coast.

The distribution of sea-ice begins with the first formation of ice in the protected inshore bays and shallow estuaries, where the coastal waters are less saline, about the end of December[2] - these areas remain ice-covered until the spring break-up. In the off-shore waters, the first ice usually forms in waters parallel to the western shores of the Gulf, in Chaleur Bay, and in the St. Lawrence River Estuary. The drifting ice from the St. Lawrence estuary is deflected against the south shore of the St. Lawrence estuary and is carried eastward by the Gaspé current; in the open Gulf the ice continues to drift eastward or southeastward under the force of the Gaspé current and strong prevailing winds. Perhaps due to the increased deflective force of the earth's rotation and winds, the ice is carried south to jam against the north coast of Prince Edward Island or southwest to jam the entrance of Chaleur Bay, or even to carry the ice into the western entrance of Northumberland Strait. The general eastward drift of the ice in both Northumberland Strait and along the north shore of Prince Edward Island forces the ice against the Cape Breton Island shore; the Northumberland Strait icefields, severely worked over, discharge through Cabot Strait with much of the ice passing between St. Paul Island and Cape North. Although the main direction of ice drift in the Gulf is counter-clockwise, in the area between Anticosti Island and the Newfoundland coast, strong winter winds with the support of the Coriolis force, drive the ice south to the exit of Cabot Strait.

The initial advance of the ice from these sources varies greatly from month to month and from year to year, in terms of speed, concentration and the supply of ice from the source areas (Fig. 1). Once formed, the ice is driven forward by strong winds so that the regional distribution of ice varies widely in terms of ice cover, ice types, ice concentration and pressure ridging moreover, the position of the ice front in the Gulf at any given time also varies greatly. The prevailing winds drive the ice into massive jams in the southeastern embayment of the Gulf and into Cabot Strait, the only outlet for the ice. The farthest easterly penetration of Gulf ice through Cabot Strait occurs between mid-February and mid-March, when the ice front may lie 100 miles east or 200 miles northeast of Sydney (Fig. 2).

The main source of Gulf ice is of local origin, being formed in Gulf waters; Chaleur Bay contributes ice to the Gulf throughout the winter. Although ice forms earlier in the St. Lawrence River than elsewhere in the Gulf, the main supply of 'river' ice is from the estuary below the Saguenay. Heavy ice from the Arctic,from Davis Strait, and Baffin Bay drifts south with the Labrador current. The arrival of the arctic ice-pack in the Strait and the maximum extent of the arctic ice-pack in the Gulf may represent the most extreme variation of ice distribution in the Gulf (Fig. 3).

This ice may reach Battle Harbour at the entrance to the Strait of Belle Isle anytime from the first week of January to the end of April: for example, in the winter of 1960, arctic ice pushed into the Strait as early as January 5; by March 16, it had jammed against the northeast coast of Anticosti Island. A more extreme example occurred in 1961: the arctic ice-pack entered the Strait on March 28, and, by April 28, the ice front had pushed southwest and west into the Jacques Cartier Passage with the front lying to the south of the Mingan Islands. The flow of ice through the Strait is erratic: the flow may either be sustained or even be suspended for a considerable period of time or it may enter the Gulf in separate "advances". A reverse flow, which seems to develop when the inflow has abated, occurs along the south shore of the Strait. It seems probable that there are years when the arctic ice-pack does not enter the Gulf, and years when there may be a more-or-less continuous flow of ice into the Gulf. Although the arctic ice-pack reaches Anticosti Island, it does not seem to reach mid-Gulf. Bergs have been traced west of Natashquan on the North Shore, they have been sighted grounded near the east end of Anticosti Island, and they have drifted south along the west coast of Newfoundland to ground on Cape Anguille at the entrance to Cabot Strait.

Average sea-ice conditions, which extend over so extensive a region and possess such wide regional and local characteristics, are extremely difficult to define. It is difficult to speak of average ice conditions in the Gulf region because of the wide variations of sea-ice conditions which occur in the Gulf, and, because wide climatic variations in the winter months have a powerful effect on ice formation throughout the region. Winters with heavy or light ice conditions can be identified - the winters of 1958 was one of the lightest on record; whereas, the winter of 1961 was one of the heaviest (Fig. 4).

In 1958, the forward edge of the ice front lay to the west of the Magdalen Islands; the ice cover consisted mainly of new and young ice-types. Quite remarkably, the southern icefields of the Gulf did not bend around Cape Breton Island to enter Cabot Strait. The last remnants of Gulf ice disappeared from the region in early May. In contrast, the ice conditions were encountered during the 1961 season; at the end of January, the Gulf was ice-covered with ice discharging heavily through Cabot Strait and drifting south

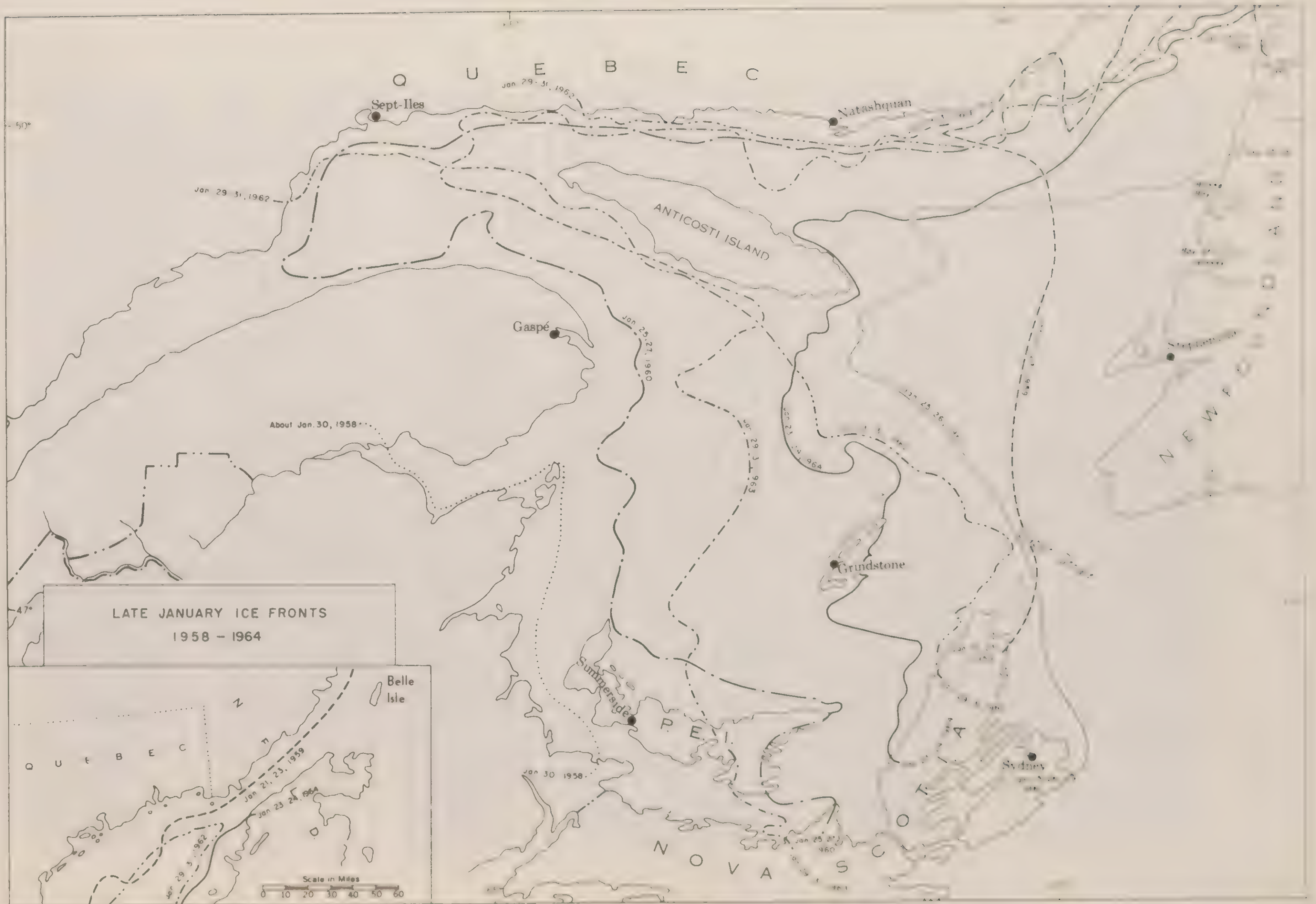
LATE JANUARY ICE FRONTS
1958 – 1964
QUEBEC
NOVA SCOTIA
NEWFOUNDLAND
ANTICOSTI ISLAND
P.E.I.
Sept-Iles
Natashquan
Gaspé
Grindstone
Summerside
Sydney
Jan 29-31, 1962
Jan 25,27, 1960
Jan 29 3 963
Jan 23 24 964
About Jan. 30, 1958
Jan 30 1958
50°
47°
Belle Isle
Jan 21, 23, 1959
Jan 23 24 1964
Scale in Miles
0 10 20 30 40 50 60

Figure 1

L-32


MAXIMUM ADVANCE OF ICE FRONTS
1958 — 1964
QUEBEC
NEWFOUNDLAND
NOVA SCOTIA
P.E.I.
Sept-Iles
Natashquan
ANTICOSTI ISLAND
Gaspé
Grindstone
Summerside
Sydney
Stephenville
Bonne Bay
Bay of Islands
Cabot Strait
Feb 19, 1958
Feb 3, 1960
Feb 17, 1960
Feb 6, 1960
Feb 18, 1959
Feb 26, 1962
Mar 2, 1963
March 3, 1964
March 12, 1963
Belle Isle
Scale in Miles
0 10 20 30 40 50 60

Figure 2

L-33

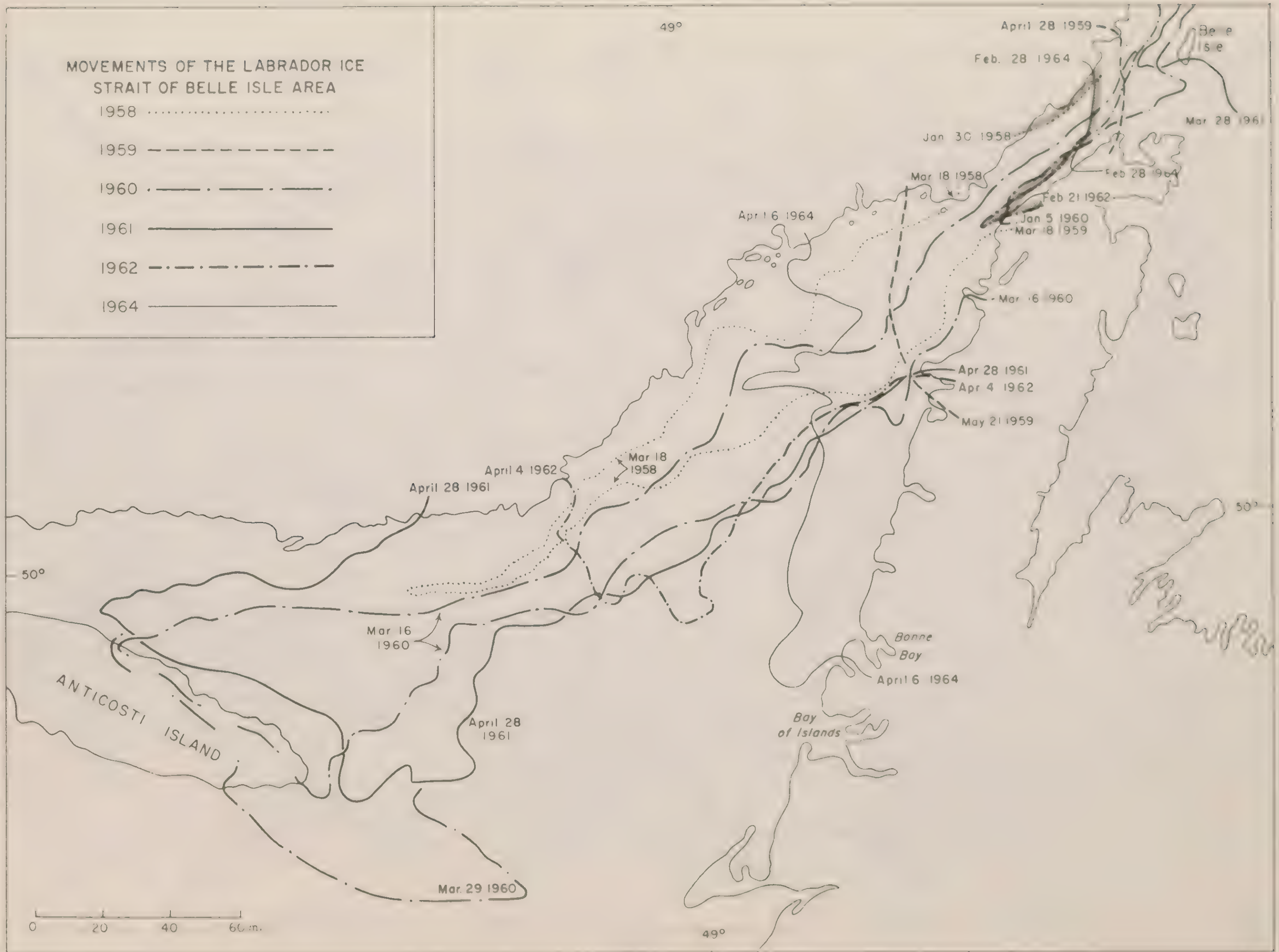
MOVEMENTS OF THE LABRADOR ICE
STRAIT OF BELLE ISLE AREA
1958
1959
1960
1961
1962
1964
49°
April 28 1959
Belle Isle
Feb. 28 1964
Mar 28 1961
Jan 30 1958
Feb 28 1964
Mar 18 1958
Feb 21 1962
Apr 16 1964
Jan 5 1960
Mar 18 1959
Mar 16 1960
Apr 28 1961
Apr 4 1962
May 21 1959
Mar 18
1958
April 4 1962
April 28 1961
50°
Mar 16
1960
Bonne
Bay
April 6 1964
ANTICOSTI ISLAND
April 28
1961
Bay
of Islands
Mar. 29 1960
0
20
40
60 m.
49°

Figure 3

L-34

Figure 4

L-31

The icefields consist mainly of winter ice (W); new ice (Vy) and young ice (Y) dominate the north-shore waters of the Gulf; the icefields of winter ice are heavily pressure-ridged (PR) in the eastern and southern regions of the Gulf.

and southwest off Cape Breton Island. By the third week of February the ice cover consisted of consolidated flows that often extended many miles across. The retreat of the ice began during the first week of March; the last ice, however, did not leave the area until after June 8.

In a heavy ice year, when air temperatures are abnormally low, there is a higher proportion of the heavy winter-ice type comprising the ice cover (Fig. 5). Strong prevailing W-NW-N winds drive the ice against the south, southeast and east shores of the Gulf. The amount of pressure-ridged ice tends to increase from west to east; thus, the most extensive areas of pressure ridges is the southeastern Gulf region where the Cape Breton coast lies directly in the path of the eastward drifting sea-ice. The ice, though deflected northeastward, is forced into massive ridges such that by mid-winter about 7- to 9- tenths of the ice surface is in pressure ridges. The ridges are estimated to be from 5 to 7 feet high. A rule-of-thumb may be used to estimate the depth to which the ice extends below the surface; that is, the ice below surface is about 4 to 5 times the height of the ice above surface. Thus, if the summits of ice ridges are 5 feet high, then the sub-surface pinnacles may extend 20 to 25 feet down. During severe ice years, the downwind coasts may be bordered by open water or by light ice.

In a light ice year, which is usually indicated by abnormally high winter temperatures,there is a much greater proportion of new-and young-ice types, pressure ridges are negligible, and open-water areas lying off down-wind coasts are much more extensive. In light ice years the most severely pressure-ridged ice occurs in the southeastern Gulf region and against westward-facing shores that lie in the path of the drifting ice.

The arctic pack-ice, which enters the Gulf through the Strait of Belle Isle, is the second major area of severely pressure-ridged icefields. Usually the south side is bordered by heavy concentrations of 9- to 10- tenths ice cover; whereas, the north side is likely to be bordered by open water and light ice.

Although the break-up of the Gulf icefields is in March and April, it presents regional variations as extensive as the expansion of the sea-ice surface in winter. In some years, the uneven expansion of open-water areas on each side of the Gulf gives rise to an ice barrier which extends diagonally from the Strait of Belle Isle to the southern Gulf. Other years occur when the Gulf-ice barrier is breached by open water, extending from Cabot Strait to the mid-Gulf region. However, the last areas to become ice-free are the catchment basin of the southern Gulf and the Gulf's northeast arm. The average date for the last ice to leave the southern Gulf in the 1958-70 period is May 15; but it has varied as widely as April 13, the earliest, to June 12, the latest. There are parallel variations in the departure of the arctic sea-ice from the northeast arm; icebergs continue to enter the Strait of Belle Isle until mid-summer. Generally, the St. Lawrence River becomes ice-free in early April; bays and estuaries of the southern Gulf usually become ice-free before the offshore ice has left the coast.

The Conquest of the Icefields of Northumberland Strait

Perhaps nowhere in Canadian colonial experience has provincial agitation been more persistent; nowhere does it dramatize more effectively the perserverance of the Canadian pioneering spirit in the attempts, first, by Prince Edward Island, and later, by provincial-federal authorities to overcome the icebarrier of Northumberland Strait. The ice barrier was a

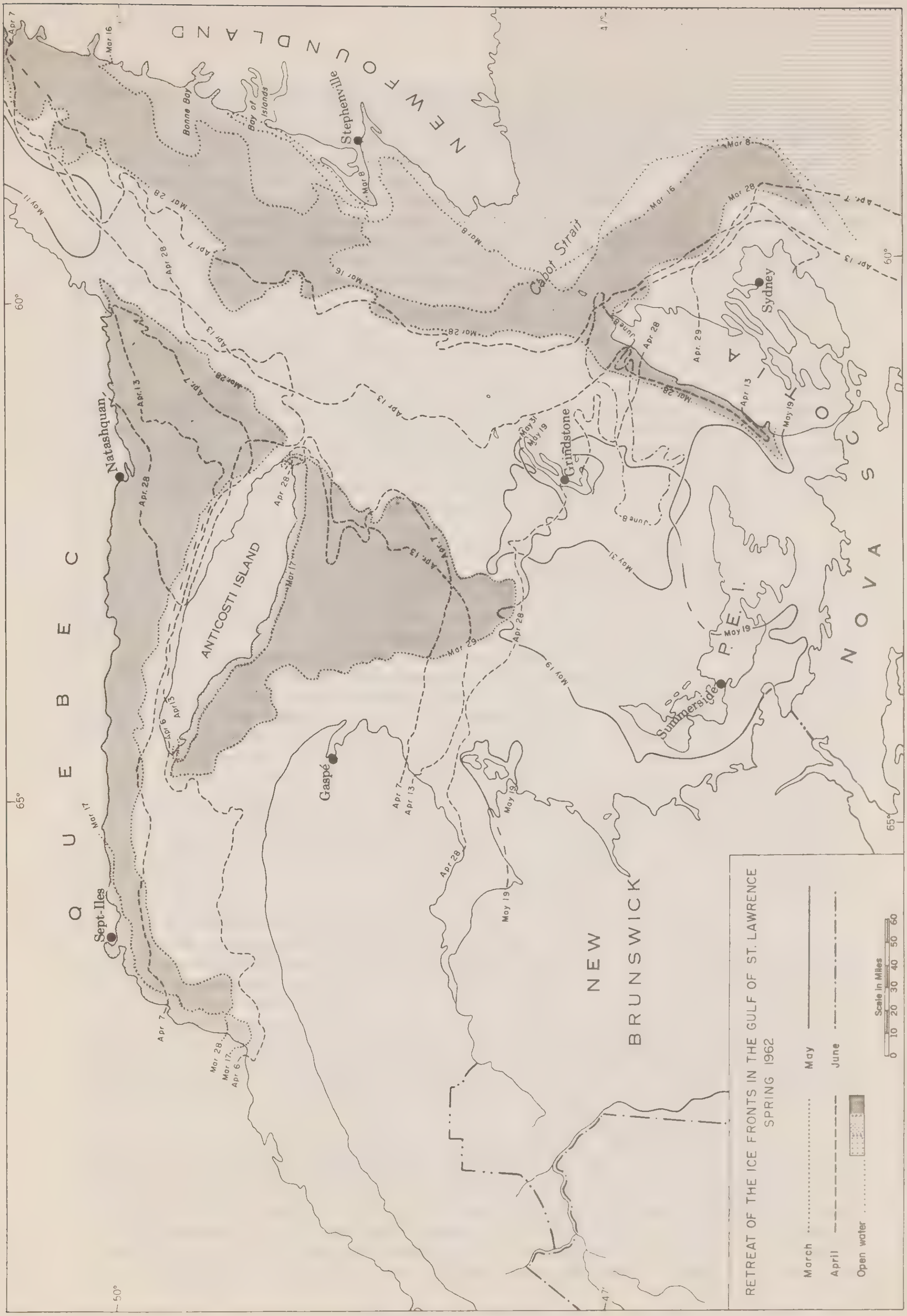
RETREAT OF THE ICE FRONTS IN THE GULF OF ST. LAWRENCE
SPRING 1962
March
April
May
June
Open water
Scale in Miles
0 10 20 30 40 50 60
QUEBEC
NEWFOUNDLAND
NEW BRUNSWICK
NOVA SCOTIA
P.E.I.
ANTICOSTI ISLAND
Sept-Iles
Natashquan
Gaspé
Stephenville
Bonne Bay
Bay of Islands
Cabot Strait
Grindstone
Sydney
Summerside
50°
60°
65°
47°

Figure 5

symbol of the Island's isolation and separation from the Mainland; to overcome it became virtually an obsession on the part of the Islanders; in varying degrees, this concern about isolation has dominated provincial politics for almost two centuries. The summer service by sailing packet was relatively free of trouble, but in late autumn the sailing vessels were laid up for winter. Prior to Confederation, the crossing of the icefields by iceboats and, after Confederation, by iceboats and steamers, provided irregular and unpredictable winter service. Thus, from the earliest days of settlement, the ice-filled waters of the Strait have loomed large in discussions on the social, political and economic affairs of the Island Province.

When the early settlers of Prince Edward Island made winter expeditions to the Mainland, they followed the Indian technique of fitting runners to the canoes. Later fishing dories, followed by rowboats, fitted with runners, were used; in the 1850s the Norwegian pram, a type of rowboat fitted with runners was adapted for the iceboat service.[3] In 1775, Governor Patterson of Prince Edward Island initiated the first official iceboat service across the 23-mile Strait between Wood Islands, P.E.I. and Pictou, N.S. Severe ice conditions and bad weather seems to have reduced this 'daily' service to an occasional one or two trips a winter.

In 1827, the Prince Edward Island Government believed a more reliable iceboat service could be provided at the 9-mile wide stretch from Cape Tormentine to Cape Travers. The government-supported service did not get underway until 1829. From this time onwards iceboat operations continued as an integral part of interprovincial communications across Northumberland Strait until 1917.[4,5] At first the iceboats made monthly trips; later a weekly service was established. At the time of Confederation a daily service was in effect -- weather permitting, which usually indicated that iceboats could not get through for several weeks or more at a time. Even in the best of weather, the crossings were slow and dangerous: the boats were rowed in open water and on the ice-fields men hauled the boats by means of traces hitched to the gunwales of the boats. That lives were not lost was due largely to the fact that the crossings were not made during threatening or stormy weather, but only when there was a chance of crossing the icefields in daylight. After Confederation from 1874 to 1917, when the first ice-working steamers came into service, the iceboats were pressed into service when the winter steamers couldn't get through.

The formation of several shipping companies in the periods 1840-42, 1852-53, 1860 and the Charlottetown Steam Navigation Company formed in 1861 (the latter operated to 1912) attempted to provide winter crossings. They operated sidewheel or sternwheel steamers which improved the summer service but failed with the onset of ice in the Strait. Later screw-driven ships entered service after 1891. These wooden vessels could not operate in the icefields and were usually tied up from December to April when the iceboats at the Capes were pressed into service. It seems apparent that the technology of design, strength and power of the ships of the period was not advanced sufficiently to provide adequate service in congested waters.

Worsening fiscal matters on the Island, resulting largely from the heavy burden imposed by the construction of the Island railway, was a major factor influencing Prince Edward Island to join in Confederation with Canada. Equally important was the view that union would bring greatly increased resources to provide efficient winter service across the ice-congested waters of the Strait. The physical limitations imposed by ice restricted the size of iceboats that men could handle, thus, except for the mails and

passengers, it was impossible to ship goods in quantity. It is difficult to assess the extent to which such limited facilities retarded the social and economic development of the Island and restricted the availability of financial resources to spur development for many years after Confederation.

In the year of Confederation, 1873-74, the only service was the irregular crossings of private vessels in summer and the irregular crossing of iceboats in winter. The islanders turned again to their perennial problem of the winter ice barrier. In 1874-75, the Dominion Government, to meet this vexatious problem, provided an old wooden steamer, the *Albert*, which, after two seasons of trials attempting to force the crossing of the Strait, was withdrawn; all further attempts with this ship were abandoned. The *Northern Light*, a wooden ship was introduced in 1876 as the first ice-breaker to provide winter sailings between Georgetown and Pictou; however, as the ice became heavier she could not maintain a regular daily schedule. The crossings became more irregular; there were long periods, up to a month in length, when no crossings were made.[6] As ice blocked Pictou Harbour in 1879, attempts were made to cross the Strait between Georgetown and Wallace, N.S. On February 25, in a crossing, the *Northern Light* sustained sufficient damage to put her out of commission for the duration of the winter. In 1882, no crossing was made between February 4 and March 28 because of heavy ice. In 1886, the Newfoundland sealing steamer *Neptune* was placed in service to work in conjunction with the *Northern Light*; heavy ice forced the withdrawal of both ships.[7] The C.G.S. *Lansdowne* was then placed on the winter service, it was found unsuitable, and was withdrawn. In the winter of 1887-88, the *Northern Light* suffered such severe damage from ice on the Georgetown-Pictou service that she was withdrawn from service. The *Petrel*, an improved icebreaker, followed. These wooden ships operated well in light icefields; none of them proved suitable in heavy pack-ice or in the yielding but tenacious masses of slush and slob ice. As in earlier days, when the ships couldn't get through, the iceboats at the Capes were pressed into service.

The Dominion Government assumed the operation of the iceboat fleet in 1885. The fleet usually consisted of 6 boats, each with a crew of six, carrying six passengers and 400 lbs of mail. The boats made the crossing together, and to force passage through heavy ice, the boats lined up bow-to-stern. The loss of life and the suffering of passengers from 36 hours of exposure in the icefields in a crossing begun on January 27, 1885 brought renewed agitation. In 1888, the Dominion Government provided the *Stanley*, the first steel passenger-ferry icebreakers as the solution to winter navigation in Northumberland Strait. The ice in the Strait proved too heavy and the ship too small and underpowered to force its way through the congested icefields of the Strait.

With the arrival of the *Stanley* a new approach to surmounting the ice problem in the winter crossings of the Strait was introduced that was to continue until the opening of the Borden-Tormentine terminals in 1917. The Department of Marine and Fisheries ran the *Stanley* on the Summerside-Pointe-du-Chêne route at the west end of the Strait for as long as possible. As the ice grew heavier, the ship was switched to the Summerside-Tormentine route; when Summerside closed, the ship was diverted to the Charlottetown-Pictou route; as this route became choked with ice, the vessel was moved to the Georgetown-Pictou or the Souris-Pictou route until all routes were closed.

The addition of the more powerful *Minto* in 1899, brought attempts to work the *Stanley* and *Minto* opposite each other or separately from different ports. Although adjustments to ice conditions gave rise to frequent variations in route patterns that improved the winter service, the ships were not successful in maintaining any form of regular service in heavy icefields. However, with two ships in operation there developed the practice of utilizing one ship on the 'western' route - Summerside to Tormentine, and the other ship on the 'eastern' route - Georgetown to Pictou. Bitter Island rivalry over the efficacy of a particular route developed. In the winter of 1902, the *Stanley* operated on the western route between Summerside and Tormentine; the *Minto* was on the Georgetown-Pictou route. The Summerside *Pioneer* noted that the railway authorities had refused to have special trains run from Charlottetown to connect with the *Stanley* at Summerside; trains regularly departed from Charlottetown to meet the *Minto* at Georgetown. In the winter of 1913, the *Minto* was on the daily Summerside-Tormentine route; the *Earl Grey*, added in 1909, was on the Charlottetown-Pictou route. During the winter, because of heavy ice conditions, the *Minto* was moved to the eastern route. The Summerside *Island Farmer* described this in its January 5th issue as:

> "A deliberate plot to keep it from being proved that the Summerside-Tormentine route can give practically as good a service in winter as in summer."

On January 22, the *Island Farmer* described the situation as:

> "A Charlottetown plot to get both the *Minto* and the *Earl Grey* on the eastern route."

From 1903 to 1909 severe ice conditions were experienced in the Strait so that the winter service was severely strained. On January 12, 1903, the *Stanley* on a crossing to Tormentine, was caught in a gale, and, becoming trapped in the icefields, drifted eastwards.[8] About mid-February, the *Minto* operating on the Georgetown-Pictou route, was sent to free the *Stanley;* in the process the *Minto* became frozen in. The passengers escaped to Pictou by dragging boats across the icefields. On March 2, the *Stanley* had drifted about 20 miles east of Pictou Island; later both steamers, locked in the icefields, circumnavigated Pictou Island. On March 17, after being locked in an ice floe for 66 days, the *Stanley* became free and towed the *Minto* to safety. During the period when the two ships were trapped in the icefields, the mail service was carried on by the iceboats at the Capes. Only a few crossings were made in 1905 from January 27 to late March; similarly, few winter crossings were made in subsequent years to 1909.

Frequent agitation in the capitals of Charlottetown and Ottawa since Confederation had resulted in the introduction of new and more powerful ships. Although these early ships failed to measure up to expectations, it was hoped they would solve a Confederation promise to provide the Island with an "efficient steam service" and "continuous communications" with the Mainland.[9] The continuing winter battle with the congested icefields of Northumberland Strait, however, had brought about a new concept in provincial-federal relations: the idea of arbitration between federal and provincial governments to solve local problems that are of national significance.

The long perilous journeys across the congested icefields of Northumberland Strait by iceboat and the irregular and unpredictable service provided by winter steamers were giving rise to a consideration of alternative solutions: causeways, tunnels, bridges and ferries were suggested. In 1885 a plan for a cast-iron tube to provide a subway linking Cape Travers with Cape

Tormentine was being considered. This proposal seems to have been the first attempt to present a tunnel concept before the federal authorities in Ottawa. In 1891 the feasibility of a tunnel between Money Point and Carleton Point, near the present ferry service between Borden and Tormentine, was investigated. The tunnel ideal seemed particularly attractive as it not only removed the winter ice problem but provided permanent connection with the Mainland. Moreover, extensive railway building in the West encouraged the Islanders to review demands for a tunnel. In 1910, the tunnel scheme was abandoned as impractical; most Islanders had become convinced that the tunnel scheme was impossible to attain. The railway car-ferry scheme was receiving widespread support; it was a compromise scheme that seemed comparatively easy to put into operation, compared with the construction of a tunnel; moreover, a car-ferry would link the Island railway with the Mainland system.

The federal government, in 1912, investigated various possible routes for a car-ferry crossing and selected Borden-Cape Tormentine route; [10] contracts for ferry and terminal connections were awarded in 1912, but because of the Great War, these could not be completed until 1917. In 1915, the icebreaker car-ferry, *Prince Edward Island*, entered service; the *Earl Grey* and the *Minto* were withdrawn. Ice conditions in the Strait in the winter of 1917 seem to have been severe: as the ice conditions worsened with advancing winter, first, Summerside was closed and the *Stanley* removed from service, next, Charlottetown Harbour was closed and the *Prince Edward Island* was switched to the Georgetown-Pictou route to provide a one-way, one-day service. This service was not entirely successful for the iceboats again were pressed into daily service at the Capes as the '*Prince*' could not get through.

With the completion of the terminal at Borden and Cape Tormentine in 1917, the *Prince Edward Island* went on a regular single daily round-trip service; moreover, it marked the final year that the iceboats were pressed into crossing the perilous icefields of Northumberland Strait.

In the years after World War I the irritations that flared up between the Province and Ottawa were basically connected with other aspects of the "efficient" and "continuous" controversy, particularly with the dependence of the Island upon one boat for access to the Mainland.[11] The growth of traffic increased sufficiently that the *Prince Edward Island* was replaced by the more powerful *Charlottetown* in 1931. However, automobile traffic had increased at a phenomenal rate so that the '*Prince*' was modified to carry automobiles and again placed on regular service in 1938. In 1941, the *Charlottetown* was lost off the coast of Nova Scotia. For fear that the Province might be cut off completely from the Mainland by the action of enemy submarines, a bomber escort was provided the '*Prince*' during daylight crossings: moreover, there were contingency plans that, should the ferry be lost, an iceboat service could be established between the Island and the Mainland.

Tourist traffic grew rapidly after World War II and was greatly aided by an improvement in highways and in the performance of the automobile. There was, besides, a rapid growth in trucking. Long delays waiting for the ferry caused irritations. Moreover, a new factor, the growth of commercialism, which places a monetary value on time, strengthened agitation for improved service. Although this agitation was directed largely at the summer service, the growth of winter traffic and the long delays waiting for the ferry in cold weather strengthened the demand for a new ferry. In 1947, the *Abegweit* replaced the '*Prince*' in service; however, the growth of traffic continued and the '*Prince*' was placed on regular service in 1955.

The normal crossing time of the *Abegweit* in open water was about 52 minutes; however, in winter when the ship had to force its way through icefields, the crossing time from January to April was longer.[12] Thus the duration of delays varied from month to month and from year to year. In March of 1952, the average crossing was almost 40 minutes longer; in 1957, the average crossing for January and February was about 25 minutes longer than the normal crossing time. There were times when the ship was delayed by as much as 9 to 13 hours. The increased passenger and automobile traffic, together with the irritation of long delays waiting for the ferry, revived demands for improved services across the Strait. It is noted that from 1948 to 1969, the number of passengers crossing the Strait had increased by 4.4 times, and the number of vehicles by 7.2 times. To provide fast and constant transit, five ships were added from 1962 to 1971; these ships, together with the *Abegweit*, have a carrying capacity exceeding 600 vehicles (the *Prince Edward Island* was retired in 1968); in addition, the CNR introduced a revised service in 1969 that is mainly oriented to the travelling public. Of these ships only the *Abegweit* and the *John Hamilton Grey* can operate under winter ice conditions; moreover, these two ships have a carrying capacity exceeding 300 vehicles. The *Abegweit's* performance in winter indicates that, to maintain a regular service, severe ice conditions encountered in the Strait exact a heavy penalty.

It may be possible to reconstruct a picture of ice conditions faced by the early ships in the crossing of the Strait between Borden and Tormentine. The summary of ice conditions shows that in the vicinity of the Borden-Tormentine crossing from 1958 to 1964, the year 1961 was the most severe and 1958 the least. In varying degrees, the years 1959, 1960, 1962 and 1964 lie between the two extremes. The table also shows that ice concentration of not less than 0.9 of the sea surface in the 1961-season persisted for about 4 months, and severe pressure ridging of the ice surface of 0.5 or greater for 3 months. For other years, the duration of ice concentrations of not less than 0.9 of the ice cover, associated with those periods of severe pressure ridging, would have severely tested ships such as the *Stanley*. Moreover, severe ice conditions in the Strait would be paralleled by correspondingly severe ice conditions in the southern Gulf region.

Summary of Ice Conditions in the Vicinity of the Borden-Tormentine Crossing

Year	Concentrations of not < 0.9 of ice cover	Concentrations of giant floes 3,000' across, exceeding 0.1 of ice cover	Consolidated ice-cover of 0.9 to 1.0	Severe pressure ridging of 0.5 or greater
1958	Feb. 21-Feb. 23	Feb. 21-Feb. 25	nil	- - -
1959	Feb. 20-Mar. 2	Mar. 5-Mar. 9	nil	Feb. 18-Feb. 22
1960	Jan. 26-Mar. 29	Feb. 1-Feb. 17	nil	Feb. 16-Apr. 18
1961	Jan. 12-May 16	Jan. 24-Mar. 18	Jan. 24-Feb. 18	Feb. 1-Apr. 30
1962	Feb. 27-Mar. 18	nil	nil	Mar. 18-Mar. 25
1964*	Feb. 1-Feb. 8	Feb. 1-Feb. 15	Feb. 1-Feb. 8	nil

*The 1964 report was not published; no survey was conducted in the 1963 season.

Light ice years reduced the strain in navigating Gulf waters in winter; severe ice years produce unwanted problems. The pressure of mining development in the northern Gulf region, industrial developments in the Chaleur region, and the rapid industrial and urban growth in the Canadian industrial heartland of the St. Lawrence valley have spurred winter navigation. It is difficult to comprehend the vast development of the Quebec-Labrador iron-ore mining operations without winter navigation through the Gulf to support it.

It is difficult to place a dollar value on the achievements of winter navigation. That it is of the utmost importance is clear. A number of examples will suffice: in the winter of 1958, over 81,000 tons of newsprint from the International Pulp and Paper Company (N.B.) mill at Dalhousie, New Brunswick were moved to the United Kingdom markets. Largely because of reduced freight handling to an east-coast port and to the better quality of the delivered product, Capt. Edwards, Marine Superintendent of the Company stated that'to get those 26 ships through was worth an extra million dollars to my company'. On March 6, 1972 three ships entered Cabot Strait to load some 12,000 tons of newsprint at Dalhousie; the ships were diverted to Saint John because of the heavy ice conditions in Cabot Strait - some 18 to 36 ships were trapped in the ice from March 4 to 6. To the normal costs of transportation from Dalhousie are added the rail costs to Saint John; there are also the added costs, incurred by delays, caused by the shortage of boxcars in Eastern Canada to move so large a quantity of freight quickly to dock-side. Finally, because of the dangers inherent in navigating ice-infested waters, winter insurance rates on shipping in the Gulf have not been reduced.

CONCLUSION

The long history of the concerted efforts of the Islanders to overcome the isolation imposed by the ice barrier, shows that sea-ice has always been a major problem in the region. The impact of ice on the early steamers and on iceboat crossings varied considerably from year to year according to the ice conditions encountered in the Strait. The slow growth in the development of adequate technology tended to emphasize the isolation from the Mainland; there was no overpowering urgency to provide a technological break-through, and the vessels, which were selected, were placed on the crossing without adequate testing of their performance in icefields. The abundant records, available on the winter crossings of the Strait, exist mainly because of the persistent agitation of the Islanders to find means to overcome the separation from the Mainland. However, compared with the Strait, (few) records are available on ice conditions in the Gulf, mainly, because there was no sustained demand from the communities of the Gulf for winter navigation. Ice conditions bordering the Gulf coast were sufficiently well-known locally that sailing ships were either put-up for winter or sailed to winter ports in the fall. The navigation of ice-congested waters today, as in the past, exacts a heavy penalty in operation and maintenance costs and in reliability of service, and with the present type of ships will continue to do so since the pattern of future ice conditions, in the Strait and in the southern Gulf region, will tend to parallel ice conditions encountered in the past.

Navigation through the Gulf of St. Lawrence and up-river to Montreal presents no serious obstacles: continuing improvements in navigation techniques, ship design, and economic necessity will bring increasing efficiency to winter navigation. The most serious obstacle to all-year shipping, in the Lower Lakes-St. Lawrence system, is the bottle-neck of the upper St. Lawrence River, from Montreal to Lake Ontario; this ice-barrier limits

navigation to the industrial heartland of the mid-continent to an 8-month period. Planners of the future, confronted with this problem, will find it necessary to determine what are the costs and benefits of present use vs. costs and benefits to complete the final link of the St. Lawrence Seaway as an all-year shipping route - expressed in costs and benefits per ton-mile. This situation is likely to arise from the continuing pressure of rising costs and declining profit of manufacturing operations that could adversely effect the economic health of the Canadian industrial heartland and the contiguous American manufacturing belt.

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DEEP WATER PORTS AND MARINE TRANSPORTATION

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PURPOSE OF PAPER AND ACKNOWLEDGEMENTS

The topic of deep water ports and marine transportation is very broad and can be examined in detail by any number of experts in various disciplines. But because this seminar is an initial attempt by officers of the Department of Environment to gain familiarity with and improve their knowledge of the coastal zone environment, this paper has been developed to give a general perspective of the interaction between deep water ports, marine transportation and the coastal environment.

Accordingly, we will examine in this paper four aspects of this subject:

1. the main current developments;

2. some considerations leading to site selection;

3. the general nature of structures required for major port development; and,

4. some of the main environmental implications of deep water ports and marine transportation.

Even within these guidelines, the topic is still very extensive, and in effect, each section of this paper could be developed into a major paper by, for example, an interdisciplinary study group. Perhaps this approach could be developed for future Coastal Zone seminars.

As this paper will examine only the major highlights in any great detail, interested parties should note that there is a great wealth of current detailed information concerning the subject of deep water ports and marine transportation in such journals as Ports and Harbours, Canadian Shipping and Marine Engineering, The Dock and Harbour Authority, and Fairplay, to name only a few. Indeed the publishers of these magazines and the contributing authors of various articles are to be highly commended for their contributions to the general fund of knowledge on the subject.

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INTRODUCTION

In recent years, the growing demands of industrial development and world growth have resulted in drastic changes in marine transportation and terminal facilities. Evidence of these changes is seen in the increased use of so-called "very large" specialized vessels to transfer greater amounts of goods over greater distances and the emergence of specialized terminal facilities necessary to load and unload such vessels.

Traditionally, industry has been based on a local source of raw material but the depletion of domestic sources of raw materials, changes in technology and discovery of substitute materials have resulted in the increased import of raw materials from alternate sources.

With the carrying of commodities over greater distances, transportation costs account for an increasing proportion of the delivery cost of raw materials to industry. Over the past decade there has been a growing realization of the potential cost savings which can be achieved through the development of more efficient methods of transportation. Thus, the development of super tankers, deep water ports and container shipping has added new dimensions to the world of marine transportation.

The operational advantages to be derived from a deep water port can simply be stated as the economies of scale which can be obtained by operating very large ships. The advantages of containerization result from the fact that unitized cargo can be handled and distributed more efficiently and economically from point of origin to destination.

As these new trends in shipping and terminal facilities are still being refined, their full impact on future shipping developments and the coastal environment are not yet known. These new fields are wide open for investigation and research.

MAIN CURRENT DEVELOPMENTS

The results of 20th Century technology have created revolutionary changes in the field of marine transportation. The entire concept of port facilities, vessel size and cargo handling has altered dramatically in recent years. It has been estimated that 99 percent of overseas freight tonnage is carried by ships, and in 1969 the waterborne commerce of the world reached 2,257 million metric tons. This expanding world trade has created demands which have resulted in a new era of marine transportation services.

This new era has of necessity fostered the development of deep water ports, supertankers and the development of the so-called magic box, the container. These developments are mutually interrelated and future growth and refinement are dependent upon coordinated research and development plans.

Port Development

Although the coast zone is affected in some way by all aspects of marine transportation, the development of deep water ports and container terminals has changed the role of the port and thus its effect on the coastal zone. The new ports, instead of simply being places for the interim storage

of goods, have become springboards for exports, and large scale receivers of imports with infrastructures and superstructures which are adapted to the new transportation technology.

The relatively simple berthing and handling facilities of the old ports have been replaced by sophisticated handling and storage facilities which not only require a large capital investment but also are linked to the industrial community of the hinterland by integrated transportation systems. The whole field of port expansion is measured in terms of size, complexity, cost and significance in maintaining essential trade.

The most impressive Canadian examples of deep sea oil terminals are found in the Canaport development at Mispec Point in the Bay of Fundy east of Saint John, and in the Gulf Oil Terminal in the Public Harbour of Port Hawkesbury in the Strait of Canso.

At Canaport, the single point mooring terminal is located 4,100 feet off shore and is linked to a 9,000,000 gallon tank farm. This storage area is in turn connected to the Irving Oil Refinery by a 16 inch pipeline six miles long. The terminal which was built to accommodate tankers of up to 350,000 DWT, cost a reported $14,000,000.

The terminal at Port Hawkesbury, with a water depth of 100 feet, was built by the Federal Department of Public Works for Gulf Oil Company at a cost of $17,154,985. It also permits the unloading of Universe class tankers of some 327,000 tons and the facilities are linked to a $100 million Gulf Oil Refinery.

To facilitate navigation, the tanker traffic is guided up the Strait of Canso by a new and intricate system of range lights, buoys and radar, a responsibility of the Marine Administration of the Ministry of Transport.

Canadian port development has kept pace with world trends in the development and use of containerized cargo by constructing container facilities at major ports. The first container terminal in Canada was opened in 1968 in Montreal but since that time, large scale facilities have been developed at Halifax, Saint John, Beauport Flats, Wolfe's Cove and Vancouver which enable Canada to compete for the world container traffic. Most of these have been provided privately by shipping interests but generally with some degree of Government assistance.

Increased Vessel Size

One of the most impressive aspects of the new marine transportation era is the development of the supertanker and the very large bulk carrier or v.l.c. Economies of scale are responsible for such vessels which may range from 100,000 DWT (dead weight tons) to 400,000 DWT with a draft of 50 feet to 90 feet. The trend to larger ships may best be described by examples.

Recently, the "NISSIKI MARU", the world's largest tanker at 372,400 DWT, was delivered to her owner, the Tokyo Tanker Company to haul crude oil from the Persian Gulf to Kiire in Kagoshima. Shipbuilders in France and Japan already visualize the construction of tankers of the order of 500,000 tons.

In Canada, the supertanker "Universe Japan", 326,562 DWT, recently unloaded its cargo of 2,350,000 barrels of crude oil from Kuwait at the Canso terminal. The vessel, which is 1132 feet long and 84 feet wide, was drawing 81 feet, 6 inches of water at the time.

The Roberts Bank Terminal in the Port of Vancouver, British Columbia, noted for its coal exports, has a loading capacity of 6,000 tons per hour to service 100,000 DWT plus dry bulk ships.

The Public Harbour of Sept Iles, Quebec, shipped 28,000,000 tons of iron ore in 1970, and had the largest traffic volume of all ports in Canada. The Iron Ore Company of Canada has built new facilities in this port for shipping iron ore in bulk carriers having a capacity of 150,000 tons.

Containerization

New vessels have also been developed to handle unitized cargo. Containers are presently carried in conventional ships built for break bulk cargo, on the decks of modified conventional vessels, in dual-purpose container and roll-on, roll-off vessels, and specialized container ships. The largest container ships now draw 42 feet and are thus too large for Montreal as well as for the St. Lawrence Seaway.

The principle of containerization has also been applied to the shipment of lumber. Loose lumber is a thing of the past as virtually all lumber is now shipped in large bundles or packages in order to take advantage of the benefits of shipping goods in large units. New lumber carrying vessels may range from 600 to 700 feet in length, 80 to 85 feet in width, 35 to 43 feet in draft and may carry up to 20,000,000 board feet of lumber. This is in contrast to the cargoes of 3- to 4-million board feet carried by the Liberty ships of ten years ago. In 1971 a new $2,000,000 lumber assembly wharf at Port Alberni was completed with sufficient water depth to handle the modern vessels. While the average vessels loaded at this wharf carry 9- to 10-million board feet, the 38,000 DWT "Resplendent" was recently loaded with 17,000,000 board feet of lumber.

In summary then, the growth of vessel size, the construction of terminal facilities to handle such deep draft vessels, and the wide acceptance of containerization are the most notable features which have recently captured the interest of those involved with marine transportation and port development.

SITE SELECTION: DEEP WATER PORTS

The parameters used to determine the site of a deep water port cannot be equated with those used to locate a "non-deep water port". The prerequisite of a deep water port, as its name implies, is deep water in the approach channel and the harbour basin itself.

Nevertheless, a systematic research program investigating other variables involved in port operations must be conducted to ensure that the port will function at its economic optimum. Such a study must necessarily include an examination of the following of special interest to those concerned with the environment:

1. The terminal facilities required to handle the incoming vessels.

2. The necessary cargo handling facilities.

3. The storage requirements for the incoming and outgoing cargo.

4. Aids to navigation requirements.

5. Variations in tidal conditions.

6. The possibility of port congestion and its effect on port operations.

7. The development potential of the hinterland and a commercial land transport system.

8. The port's potential effect on the local environment.

It is necessary to examine some of these considerations in more detail.

As previously inferred, the prime consideration in new harbour development is the channel and harbour depth. In the port, a depth of 20 to 35 feet was at one time considered satisfactory for general cargo vessels, but the new deep draft container ships demand approximately 45 feet. Bulk carriers and tankers of 1960 which had a draft of 30 to 35 feet have now been replaced by larger bulk carriers and supertankers which draw at least 45 feet and on up to 100 feet.

Few harbours can offer approach channels and mooring areas of such depth, and those that can, such as Halifax, Canaport and Port Hawkesbury stand to benefit tremendously. In fact, the east coast of the United States offers nothing to compare with the natural deep water of the Canadian east coast.

Dredging existing channels and harbour basins to accommodate the deep draft vessels is an expensive and largely unrealistic proposition. For example, it is expected to cost $99,300,000 and take three to four years to increase the depth of the Baltimore harbour from 42 feet to 50 feet. It is therefore reasonable to say that the location of deep water ports has been predetermined, to a great degree, by the natural formation of the coastline.

The development potential of the hinterland will determine the capacity of the Port to attract new port oriented industries. Great ports go hand in hand with massive industrial and population concentrations with all the environmental implications these bring.

These are the factors affecting the selection of deep water port sites which have direct environmental influences. Others are more economic in nature but all are interrelated.

Variations in tidal conditions have a major influence on wharf construction costs. A wharf must provide a minimum depth of water at low tide. Construction costs are determined in part by the height of the wharf above sea bottom such that a high tidal range will simply add correspondingly to wharf costs. A high tidal range does have the advantage of course of providing a greater flushing action of harbour waters.

Some extensive harbour operations can be condensed into very small areas but congestion can result in very costly vessel delays. Goderich Harbour, Ontario, measures only approximately 3000 feet by 900 feet but this little port, the site of a rock salt mine, handles nearly 2 million tons of cargo per annum. Port Cartier, Quebec, has an artifical harbour measuring only 2700 feet by 500 feet yet it handles some 12 million tons of cargo per annum. By contrast, the wharves of the Port of Montreal are spread throughout a river shoreline of 42 miles to handle 25 million tons of cargo of all kinds.

The amount of land available for port development is also a factor in site selection. Deep water oil terminals require upland storage areas for oil tanks. Container terminals require 12 to 15 acres per berth for storage and marshalling yards. In Port Alberni, the ten acre storage yard adjacent to the new assembly wharf provides the necessary space for packaged lumber cargoes of up to 23 million board feet.

Having determined the adequacy of the water depths and port land and facilities, an effective aid to navigation system must be available to guide these great ships to a safe berth in the port. The Canadian Marine Transportation Adminstration, Ministry of Transport, is currently completing a very comprehensive system of aids to navigation including a Decca system which will reach a ship 50 miles out on the ocean and guide it to the channel where mid-channel buoys equipped with electronic devices will take over. As a vessel moves into a more restricted channel, a more detailed system of lights and beacons combines with radar surveillance and ship to shore voice communication to bring the ship safely to berth. The present program of improvements will cost $1,500,000 when completed next year.

THE GENERAL NATURE OF STRUCTURES REQUIRED FOR MAJOR PORT DEVELOPMENT

The recent trends in port development have complemented the advances made in the field of marine transportation. Specialized ports, such as deep water oil terminals have been constructed to facilitate a specific industry, and major established ports have incorporated a container terminal alongside the existing facilities of the long established port. Due to the trend toward specialized ships and mammoth tankers, modernization and expansion keynote recent activities at the major ports on the world trading routes. The push is on to make one's port the most attractive to operators of these specialized vessels. The harbour with a few shallow water jetties, limited storage space and unloading facilities consisting of strong-armed stevedores is a thing of the past and perhaps a piece of nostalgia.

Container Facilities

The capacity of a container berth is staggering in that it can handle more than 500,000 tons per year compared to about 120,000 tons for a conventional berth. Some are reported to have gone beyond this now to 800,000 tons. It is estimated that one-half the land area and one-seventh the length of wharves will be required to serve a port adapted to container ship traffic. It can be seen that the structure of a container terminal must necessarily include a large amount of land, not only in the initial stages of development but for future expansion should such a need arise.

Perhaps to illustrate more fully the nature of the structures of a container terminal, it would be appropriate to briefly describe the facilities at Canada's largest terminal facility, Halterm's Pier C at Halifax. The terminal covers an area of approximately 56 acres in the south end of the Port of Halifax and provides the following:

1. a water depth of 50 feet at the berth,

2. 1,775 feet of dock face which will accommodate any two of the largest container ships in service,

3. two container gantry cranes which operate the full length of the dock with a lifting capacity of 89,600 pounds; the cranes will handle 1,100 containers daily during Halterm's 21-hour work day,

4. live storage capacity of 4,377 twenty-foot equivalent containers,

5. a loop track of 5,000 feet inside and around the perimeter of the terminal area to receive and make up unit trains,

6. four rail stub tracks with a capacity of 17, 89-foot rail cars each, or 272 twenty-foot equivalent containers,

7. a rail track parallel to the face of the wharf to permit the handling of containers directly between vessel and rail car,

8. a modern consolidation shed of 30,000 square feet and a covered platform 130 by 40 feet attached to the shed,

9. fully equipped, modern, equipment maintenance shop,

10. two storey terminal office of 6,000 square feet. The terminal is rail oriented and 90 percent of all containers are moved in and out by rail.

These facilities or structures and others which have not been mentioned, such as straddle carriers used to transport containers in the yard, are all basic requirements of modern container terminals.

Offshore Terminals

The general structure of deep water oil terminals has also become very specialized, because the dynamic interaction of growth in oil consumption, growth in tanker demand and growth in tanker size has led to a need for terminal facilities which could not be satisfied by conventional piers in protected and already congested natural harbours.

As the trend to larger bulk carriers and supertankers eliminated ports of call which could not provide deep water, the offshore terminal was subsequently designed to, in effect, bring the terminal to the ship. Basically these terminals are used to transfer cargo between shore tankage and tankers via underwater pipelines.

Offshore terminals can be classified in three main types; sea islands, conventional or multi-buoy moorings, (MBM), and single buoy or single point moorings, (SBM) or (SPM). In reality each terminal is a system with three major components:

1. a means for holding the tankers in position;

2. a means for transferring the cargo from the tanker's manifold to a manifold on either the loading platform or to a sea bottom manifold; and

3. an underwater pipeline to transfer the cargo between the shore and manifold.

The type of offshore terminal selected for use is dependent upon many factors such as wind, wave current, sea bottom and soil conditions, manoeuvering requirements, depth of water, requirements for providing stores, oil volumes and ship sizes to be handled, initial investment and operating and maintenance costs. The site of the facility must provide safe access and as much protection as possible for the moored ship and must be designed and constructed with a full knowledge of the local marine environment. Thus each terminal is unique in that it is suited to its own environment.

In general descriptive terms sea islands are jetties, extended to deep water, where ships berth in much the same way as they do at a normal pier, and therefore require an area more sheltered from waves than the buoy type moorings. Wave heights in excess of three feet become restrictive with this type of mooring. At MBM's, the tanker is held in a fixed position by lines running to a predetermined number of buoys. At SBM's the tanker is in effect swinging on a bow anchor and can rotate freely and safely with wind or current. Such moorings are ideal in offshore locations where sea and weather conditions may be severe. Because SBM's require more sea room than other types of moorings, their use is often limited.

The pipeline connecting the terminal with the onshore storage facilities is constructed of the appropriate thickness and grade of steel to resist various internal and external forces that the pipe will be subjected to during construction and operation. The line is protected from corrosion and abrasion and if necessary, it is buried below the sea floor.

As the actual unloading of the vessel takes place through hoses linking the tanker and the mooring buoy, the possibility of an oil spill exists, but an offshore terminal designed to good engineering standards, installed to stringent specifications and operated and maintained in accordance with good operating practices will be a safe, operable facility.

ENVIRONMENTAL IMPLICATIONS OF DEEP WATER PORTS AND MARINE TRANSPORTATION

In this day and age of environmental education and general outcry by so many people against all types of pollution, the phrase "environmental implications" may have a detrimental connotation when associated with ports and marine transportation. But this is not necessarily the case.

Disasters such as the grounding of the "Arrow" in Chedabucto Bay and the "Torrey Canyon" on Seven Stones Reef off Land's End, Cornwall, England, tend to reinforce the detrimental negative response in people.

Oil pollution, with dead waterfowl and despoiled swimming beaches springs to the minds of the public while they forget the fact that only approximately 2.5% of the total amount of oil spilled into the oceans is the result of tanker collisions and groundings. Commodities, such as oil, which are the basis of the mechanized world, must necessarily be transported great distances from their geographic origins to the refineries and eventually to their final destinations as refined products. During this time, the cargo is subject to a great deal of handling which in turn is of course subject to human error. This error may be for example in the form of poor judgement while navigating, or failure to repair broken equipment, and the final result of such an omission or mistake can often be an accident which is seriously damaging to the coastal environment.

Such reasoning is hypothetical but none the less realistic. The same can be said concerning the environmental implications of deep water ports and marine transportation. Each individual development must be judged in relation to its local environment and its own merits.

It is not reasonable to label a deep water oil terminal as beneficial because it and the adjacent oil refinery will provide employment and develop the economy of the area while at the same time condemning the supertankers which deliver the crude oil because the possiblity exists that the vessel may run aground or collide with another vessel and spill 50,000,000 gallons of oil into the marine environment.

We do not have a list of the environmental implications of deep water ports and marine transportation possibly because the long term effects of such developments are not yet known. It is possible to extrapolate the detrimental effects of marine accidents from the experience of the "Arrow" and the "Torrey Canyon" but if no such accidents occur and if developments in the various fields of marine transportation are planned with the preservation of the environment in mind, it is entirely possible that the total effect on the environment will be minimal.

Thus the environmental implications of deep water ports and marine transportation, whether they be boon or bane to the coastal environment, depend on the course of events of the daily movement and manufacture of goods along the coastline.

<u>Marine Implications</u>

A major source of marine pollution undoubtedly stems from the discharge of oil, inadvertently or intentional, into the marine environment. Although the exact total annual influx of oil into the sea is not known, it probably ranges from five to ten million tons. This total includes oil from the washing of oil tanks at sea, pumping of bilges, in-port losses, collisions and groundings, as well as oil from untreated domestic and industrial works.

If a tanker accident does occur in the coastal zone and a great deal of oil is lost as a result, the effects on the environment in general terms are readily identifiable as the following:

1. The obvious eyesore, visual pollution, which generates most of the popular concern.

2. The loss of amenities and livelihood which can have serious socio-economic effects upon the local society.

3. The absorption of hydrocarbons into the water column and their ingestion by micro and other organisms which places them in the protein cycle and the human food chain.

4. The potential of an overwhelming disaster to local and migratory birds and mammal life that use the water.

Although the construction of very large supertankers has come under fire from some quarters, it is interesting to note that an independent survey conducted by Alcan Shipping Services Ltd. of Montreal indicates possible advantages of such vessels to the environment. The survey finds that the expected doubling of crude oil production from 2 billion tons in 1969 to 4 billion in 1980 will not result in a proportionate increase in tankers. The forecast is for larger tankers and a risk factor less than for smaller tankers. The survey is aware of the fact that this smaller risk factor could be more than offset by the increased potential spill factor in the event of an individual accident. But the combination of fewer though larger vessels, improved navigational aids, and the specialized skills of the crew have the potential to decrease the risk of collisions and groundings.

It is anticipated that the marine transportation industry will become increasingly regulated and that recognition of responsibility with regard to marine accidents will increase rather than diminish. In this regard several agencies have been formed, bills passed and plans adopted to combat the effects of pollution in the coastal zone.

The tanker owners of the world have created a voluntary organization, TOVALOP (Tanker Owners Voluntary Agreement concerning Liability for Oil Pollution), to take constructive action with respect to oil pollution. The plan provides that a participating tanker owner will reimburse national governments for expenses reasonably incurred by them to prevent or clean up pollution of coastlines as the result of negligent discharge of oil from one of their tankers.

The oil companies have recently developed a similar agreement to TOVALOP. The scheme called CRISTAL (Contract Regarding an Interim Supplement to Tanker Liability for Oil Pollution) provides funds for the payment of claims up to $30 million to persons suffering damage resulting from an oil incident. These two programs are not infallible but the industries concerned have accepted responsibility for detrimental results of some of their operations.

The Government of Canada has also taken bold steps to reduce the detrimental environmental implications of marine development. The Arctic Waters Pollution Prevention Act of June 26, 1970, prohibits the deposit of any waste in Arctic waters a distance of one hundred miles from shore from ships or land based operations, and makes the owners of ships and their cargoes and persons conducting land based operations civilly liable for any such discharge.

In July 1970, the Federal Government issued an Interim Federal Contingency Plan for Combatting Oil and Toxic Material Spills. The plan deals with the federal participation in the clean up of oil spills, particularly in the Arctic, the East and West coastal areas and the Great Lakes international zone. A field manual has been set up to ennumerate the best current methodology for combatting spills of oil and other toxic materials.

Just recently, an important amendment was made to the Canada Shipping Act effective February 15, 1972 whereby a charge of 15 cents per ton is now being levied on bulk oil imported into Canada by ship and bulk oil shipped by water from any place in Canada. The cargo of oil must exceed 1000 tons. The money collected will go into the Marine Pollution Claims Fund and will be used to pay for clean up operations and pollution damage caused by marine accidents.

Other groups and organizations are striving in the same vein to ensure the continuing existence of the coastal zone environment, free of any adverse effects of the new era of marine transportation.

Landward Implications

This aspect has already been touched on in this paper but bears reviewing here to highlight the effects on the land adjacent to the coastline. This is mainly in the form of industrial development of the land immediately adjacent to the port and the expansion of the actual port facilities. The environmental implications then are those which are associated with the expansion of heavy industry in any area. For example, the Canaport development at Mispec Point which employed about 1,100 persons in construction, is expected to be a catalyst for economic development.

Thus the industries associated with the oil and the goods and people required to service the industry and oil carrying vessels in port will undoubtedly alter the face of the port hinterland.

This development, as any other development in any area of the country, should be coordinated within the master development plan of the area. The principles of good land use planning should be followed, especially if the area is in the initial stages of development. This will ensure the best use of the land and preservation of the environment for future generations. If this plan of action is followed, there will be no detrimental effects caused by the landward development of port facilities and associated industries.

Dredging and Pollution

One of the very significant areas of common interest to those concerned with the environment and with deep water harbours is the new concern being given to deposition of dredged spoils. Practically all of the world's shipping requires assistance at some point or other through the improvement, by deepening, of natural waterways. Oftentimes the material to be dredged from a harbour or river bottom has become polluted in one way or another by municipal or industrial wastes. In the past, the practice has been to deposit this dredged spoil on the adjacent shore with a view to creating land for related harbour or industrial uses or alternatively, to pump or barge it to deep water where it dropped to the bottom and did not interfere with navigation.

On the international level, the World Dredging Association has set up a committee, WODCON (World Dredging Conference) to develop a handbook on marine ecology and dredging. The initial task of this committee is to collect and compile case histories of dredging projects where there has been an environmental problem. These case histories will then be used to develop guidelines for planning and conducting dredging operations and the development of a research program. Locally, the dredging programs must continue in cooperation with all government agencies, federal, provincial and municipal, which are engaged in pollution control.

With the increased attention being given to water pollution, both Federal and Provincial Government authorities have insisted that dredged spoil which might in any way disperse contamination must be deposited on shore property rather than returned to the water at another location. If this dredged material is fine it may not be suitable in future for carrying the heavy loads which might be required of it for industrial wharves or other structures, yet it could rest harmlessly on the lake bottom in deeper water. Oftentimes there is no adjacent shore property on which to deposit good material and indeed there may be no immediate demand for the material in the nearby area. Accordingly, those responsible for improving the channels are immediately confronted with much greater cost considerations.

Recent illustrations of this may be found in the Great Lakes on the Kaministikwia River at Thunder Bay where a much-needed dredging project has not been carried out this past year simply because of objections to the deposition of the spoil in the deep waters of Lake Superior. Land acquisition along the river for the deposition of the material is prohibitively expensive. The port administration responsible for this dredging work simply does not have adequate funds to pay this additional cost.

Another similar illustration, though even more serious is to be found on the St. Clair River where by international treaty the Government of Canada is required to maintain certain channels at agreed depths. The cost estimate for this dredging, $2 million under the present policy, is escalated to $4 million if this contaminated material is to be deposited ashore.

As I mentioned, this concerns more than one Government Department. In addition to the Federal Department of Environment we also have a Provincial Department of Environment and the Ontario Water Resources Board which is concerned with the purity of the water.

Historically, navigation has always been given priority rights on water in keeping with the historic policy of "freedom of the seas". If, however, the forces of nature insist on shifting the bottom of navigation channels and erasing the effects of deep dredging designed to assist the economy of the nation through economical water transport, and at the same time harbour and other marine authorities are not equipped or financed adequately to make other arrangements, navigation in deep water will inevitably be severely restricted, if not brought to a standstill altogether. Without going into any legal discussion as to priority rights or anything of that nature, I think you will appreciate from the foregoing that we are now confronted with a very real problem which you the environmentalists, and we the marine transportation authorities must resolve as quickly as possible.

DISTINCTIVE NEW SHIPS OF 1971

VESSEL	CARGO	LENGTH FT./IN.	BEAM FT./IN.	DRAFT FT./IN.	D.W.T.
Columbus New Zealand	Containers 1,187	636	96	32-4	22,000
Euroliner	Containers 876	798-6	98-5	32-6	23,100
Castillo de la Mota	Coal, Ore Grain 64,172 cu. metres	696	102	41	55,000
Aegean Wave	Ore, Coal, Oil	856	136	52	112,257
Eiko Maru	Oil Tanker 277,850 cu. metres	1,049	166-10	65-8	230,000
Esso Caledonia	Oil Tanker	1,143	170	65-6	250,000
Halcyon The Great	Tanker 9,993,000 cu. ft. capacity	1,090	149-7	67-9	226,000
Hoegh Hill	Ore/Oil Carrier	1,069-6	170-7	67-3	245,323
Hudson Venture	Tanker	1,117-2	170	65-10	254,520
Jarl Malmros	Oil/Ore Carrier	1,075-6	164	62-10	215,500
Nisseki Maru	Oil Tanker 119,000,000 Gallons	1,138-5	177-3	88-7	372,400

SOURCE: Marine Engineer/Log - Dec. 1971

USE CONFLICT IN MARINE CONSERVATION IN THE STRAIT OF GEORGIA

W. N. English[1]

These remarks are directed to one of Canada's coastal areas - Georgia Strait, as an example of the use conflicts which must be resolved in marine conservation.

THE SETTING

Georgia Strait is an inland sea over 100 miles long and up to 30 miles wide with a deeply indented shoreline and a wide variety of indigenous and transient resources. The surface waters of the Strait exchange with the open ocean on the average about once a month, and the deep waters about once a year. Except for a few areas of restricted circulation it is well oxygenated and under-supplied with nutrients.

The local climate is mild and rainy in winter, and cool and showery in summer, which permits year round commercial and to an appreciable extent, recreational marine activity.

About 1½ million people (70% of British Columbia's population) live around the Strait, the bulk of them in the lower mainland near Vancouver. This population increased some 30% in the past decade, mainly through immigration.

British Columbia's industry is to a large extent resource based. Forest products are worth annually about $1,000 million, mineral industries $500 million, tourism $400 million, agriculture $200 million and fisheries $100 million. Except for the mineral industries a large fraction of this commercial activity is in and around Georgia Strait.

Marine transportation is another important activity. British Columbia exports each year more than 60% of its resource products. These exports in 1969 were worth $2,300 million and goods worth $1,100 million were imported from outside Canada. Vancouver handled 54% of the international shipments and 24% of the coastal shipments. Other ports on the Strait of Georgia account for a large part of the remainder.

NATURAL RESOURCES

The scenic and recreational values of the area attract each year the largest part of the some two million visitors who come to British

[1] Marine Sciences Branch, Department of the Environment, Ottawa.

Columbia and who make tourism the province's third largest industry. These same values have a considerable influence on the rate of population growth.

The marine life of the Strait contributes a lot to its attractiveness, as well as supporting a substantial industrial activity. There is great variety of plant life ranging from plankton blooms to forests of giant kelp. The Strait contains major migration areas - two million waterfowl and tens of thousands of shore birds pass through it each year - and dozens of sea bird colonies. It contains the major wintering area for the rare trumpeter swan, and a large fraction of the continental nesting area of the bald eagle.

It is frequented by a variety of mammals such as seals, sea-lions, whales, porpoises, otter and mink, and also contains unusual land plants, such as the arbutus and Garry Oak, which are tied to the marine environment.

The Strait has large populations of oysters, clams, shrimp and crab and some abalone which, where they are not contaminated by sewage, or adversely affected by wood wastes, are used commercially and pursued recreationally. Both commercial and sport fishing have always been important to the area. The major fishery is of course for the five species of Pacific salmon. The Fraser River supports one of the largest salmon populations of any river in the world, over one million fish every year. There are, or were, salmon runs to virtually all of the significant streams flowing into the Strait.

Other sought-after fish are ling-cod, a variety of rockfish and bottom fish, and the steelhead which is a close relative of the Atlantic salmon. One of the most abundant fish in the Strait is the herring, which is an important food for larger fish, birds and mammals. Herring spawn in over 50 localities where the aquatic vegetation is suitable covering a shoreline distance of 200 to 300 miles. After several lean years when commercial fishing was prohibited, a selective fishery for human food use has been permitted.

COMMERCIAL ACTIVITY

Forest products is the predominant industrial activity. On the shores of the Strait there are six large pulp mills, with a total capacity of several million tons per year. There are 20 large lumber/plywood mills, over 50 smaller sawmills, and some 230 wood manufacturing plants. A significant chemical industry provides pulp and paper chemicals and glues.

British Columbia's flourishing mineral industry is mainly in the interior of the province - only one iron, one limestone and one moderate sized copper mine are located on the Strait. There are four oil refineries in the Vancouver area, but their combined capacity is only about one quarter that of a typical large U.S. or European refinery. A refinery in this large category is under construction at Cherry Point just south of the American border, and its presence is particularly worrisome since most of its crude oil is slated to come down the coast and through the southern (U.S.) Strait by tanker.

Commercial fishing activity to meet local needs harvests oysters, clams, shrimp, crab and ling-cod and bottom fish. The most lucrative fishery is trolling for chinook and coho salmon, in which 100 to 200 boats participate over the spring to fall period, and seining and gill-netting for

sockeye, pink and chum salmon which occupies several hundred boats in the late summer and fall.

Sea transportation in the Strait largely involves forest raw materials or products, and bulk cargoes from inland sources such as wheat, coal, potash and sulphur. In 1970 the Port of Vancouver had 16,000 arrivals (44 per day) of 51 million gross tons and the Straits of Georgia and Juan de Fuca had 17,000 plus an additional 11,000 ferry arrivals (30 per day).

USE CONFLICT

Conflict of interest between different users of the Strait is nothing new. For decades logging has threatened salmon spawning streams, wood waste from booms and mills has smothered oysters and clams, and fishing boats and ferries have caused each other damage and inconvenience. Now the exploding speedboat population threatens the sport fisherman, the sailboat and the bath-tub racer, while all of these menace the scuba diver. And effluents of all kinds degrade the seawater used by fish, birds, marine mammals, and man.

The new factor is the increasing scale at which all this is going on. More and more people mean more industry, more water traffic, more engines of all sizes, with their spilled and unburnt fuel, more sewage, more wood debris, more plastic bags, bottles and beer cans. If the North Atlantic is showing some effects of man's activities, it is clear that semi-closed coastal waters such as the Strait of Georgia are faced with potentially serious degradation over the next few decades. They are faced even sooner with the loss of much of their scenic charm and recreational attractiveness through wasteful use and piecemeal development.

MANAGEMENT OF CONFLICTING USES

Land management cannot be ignored in marine conservation because of the dependence of many marine species on the adjacent shore, and because of the richness and sensitivity of the easily accessible intertidal zone. The shores are very important to the scenic and recreational enjoyment of the marine environment, and it is highly desirable to include the land to a distance of about 1000 feet from the highest tide line in any marine conservation program.

Fortunately the Strait of Georgia has large tracts of provincial land, and some lands under Federal jurisdiction, which are still undeveloped. The Province has established in the area over 30 Provincial Parks which have water frontage. In addition to five ecological reserves under the International Biological Program, there are four federal and one federal-provincial bird sanctuaries. But there are also large areas in the southern Strait which are threatened, from the scenic and recreational point of view, by population pressure and commercial development.

Perhaps the most difficult aspect of marine conservation is the coordination of the efforts of all the different levels of government, in a situation where their respective jurisdictions are not yet entirely agreed. In the federal-provincial sphere in British Columbia, the relevant existing legislation is contained in not less than 17 federal and 9 provincial Acts, of which the most important are those concerning shipping (federal) and fisheries, parks and water (federal and provincial).

Conservation in this framework can only be achieved through cooperation. As far as the Strait of Georgia is concerned, substantial progress is being made.

It is clear that water quality management is a key, if not the key element in marine conservation. Unlike the situation on land, where a line can be drawn around a conservation area, and development permitted to take place under local control outside its limits, the water mass knows no boundary. Water quality must be monitored, zoned, and managed, over the whole coastal area that can affect the conservation area. In some cases this will mean out to the limits of Canadian waters - or beyond.

ON THE POSSIBLE MODIFICATION

OF TIDES BY MAN

G. Godin[1]

Tidal forces are exerted on a celestial body whenever it is subjected to the gravitational influence of another celestial body. We do experience tidal forces on the earth because of the presence of the moon. At first sight, the tidal influence of the moon appears very slight: compared to the earth's own force of attraction which accelerates a particle of unit mass to a value of g, the lunar tidal force would accelerate it to a value of

$$.179 \times 10^{-6} \text{ g}$$

or less than two millionths of g. This force is all pervading though and if we consider its action on the mass of the oceans which amounts to 1.407×10^{12} tons (Sverdrup et al.) the total tidal force exerted on it amounts to

$$2.469 \times 10^{12} \text{ tons m/sec}^2$$

We could consider checking this force on the oceans by covering them with a canvas and hiring a gang of men to pull on the canvas in order to counteract the tidal force. A pull of 500 kg m/sec^2 is about the best effort we may expect from each worker in the gang. In this case we would need 4.938×10^{12} or 4938 billion men to do the job. This figure gives a fair indication that humanity will never be in a position to counteract directly the action of tidal forces on the earth.

Another way to reach the same conclusion is to compare the order of magnitude of tidal wave lengths with the average length of man made maritime works. The oceans have a mean depth of 4000 m; the tide has a period of about 44700 seconds. Therefore the wavelengths of tidal waves in the oceans are of the order of

$$L = T(gh)^{1/2} = 8848 \text{ km}$$

Even if the oceans had a mean depth of 1 metre, a typical wave length would be 140 km. In contrast, our harbours and jetties seldom amount to more than a few km. It makes it hard to conceive how we could build works in the oceans which could have a sensible effect on the tide.

On the other hand we do know that the tide may be modified in time at a given locality. An indication of this fact is the development or deterioration of bores in rivers. Bores are the most spectacular forms of tidal waves and they attract much attention. For instance, there have been reports of a large bore in the Petitcodiac River near Moncton. Still if you go bore watching in the Petitcodiac River nowadays, you will notice no bore at all at mean tide and only a very humble ripple at spring tide. The deterioration of

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this particular bore is attributed to a modification of the bed of the river which itself has been triggered by the erection of a causeway, therefore to geological forces which are infinitely more powerful than all the forces which man can apply.

We retain therefore the conclusion that tides may be modified.

We now take a look at the Gulf of St. Lawrence and evaluate the tidal force acting on it. The mass of water held by the Gulf is 3.08×10^{13} tons and the tidal force acting on it amounts to

$$5.314 \times 10^{7} \text{ tons m/sec}^{2}$$

This looks mighty enough but if we compare this figure with the force exerted by a wind of 18 m/sec (stress of 9.20 $g/cm/sec^2$) (Sverdrup et al.), the total force exerted by this wind over the area of the Gulf (2.38×10^5 km^2) amounts to

$$2.19 \times 10^{8} \text{ tons m/sec}^{2}$$

more than four times as much as the tidal force. This result is very strange and becomes even stranger when we notice that the tide in the Gulf has amplitude of at least 4 m and the force necessary to lift this mass of water is

$$9.581 \times 10^{12} \text{ tons m/sec}^{2}$$

more than a hundred thousand times as much as the local tide force.

The explanation to this mystery is that the tide in the Gulf of St. Lawrence is created by the tide in the Atlantic Ocean and not by the local tidal forces. This last observation allows us to move in and impress our power on the tide. If we sever the connections of the Gulf with the ocean we will eventually prevent 9.58×10^{12} tons m/sec^2 of tidal force from entering it and effectively remove all tidal oscillations from the area. Such a feat is completely within contemporary engineering capabilities: all we have to do is block Cabot and Belle Isle Straits. This deed, however, would be more mischievious than ingenious: besides proving a point, we would achieve very little else.

Rather than cutting off the tide we may also put it to work, like in a tidal plant. By this very action though, we once again will alter the tidal regime and under certain conditions, we may inhibit the tide which we intend to exploit, like in the Bay of Fundy (Duff, Yuen). The reason why the establishment of a tidal plant modifies the tide is that the closure of the Basin by the necessary dam alters fundamentally its configuration. In addition, the exploitation of the tidal energy present in the Basin alters the previous distribution and exchange of tidal energy present in the area exploited and unavoidably leads to a new tidal regime determined by the selection of a given scheme of exploitation (Godin).

We have avoided in these notes a direct discussion of the actual mechanisms of tidal excitations and the responses of basins to tidal forces, but I believe that our heuristic approach still leads us to the following conclusions:

1. The direct modification of tidal forces is beyond the reach of man.

2. The manipulation of tides in the oceans at large is also not to be contemplated.

3. The modification of the tide in relatively small basins linked to the oceans is within our reach because we can effectively modify the linkage and the response of the basins to the tide in the ocean.

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HUMAN IMPACT ON ESTUARINE HABITAT

R.D. Harris[1] and E.W. Taylor[1]

DEFINITION AND DESCRIPTION OF ESTUARIES

An estuary has been said to be a semi-enclosed body of water having a free connection with the open sea and within which the sea water is measurably diluted with fresh water deriving from land drainage (Cameron and Pritchard, 1963).

Recent research has helped to clarify the complex and unique roles that marshes play in coastal estuarine systems. Briefly, they are organic factories, traps for sediments, reservoirs for nutrients and other chemicals, and the productive and essential habitat for a large number of invertebrates, fish, reptiles, birds and mammals. Annual plant growth and decay provide continuing large quantities of organic detritus as one of the major components of the cycling of nutrients in estuaries (Cronin and Mansuetti, 1971).

Estuaries are a variety of complex ecological systems totally interrelated to form an environment that we are just beginning to understand. They are a remarkable system for the containment and efficient utilization of organic matter, water, minerals, and sunlight.

The salt water wedge pushed along the estuary bottom by the incoming tide brings in rich nutrients from the ocean. Currents and tides circulate and recirculate fresh and salt water, thus distributing these rich foods throughout the sloughs, inlets, and lagoons.

The estuary itself is also a producer of nutrients. Microscopic plants flourish in the water. Salt marsh vegetation, nourished in the rich waters brought from the ocean at flood tide, produces enormous yields of organic matter. In addition, mud flats and shore areas alternately covered and exposed as the tides change, produce a variety of small animal life such as worms, snails, and insects on which larger organisms feed. In turn, these organisms are the foundation for the food chain that is so vital to fish and wildlife production.

Because they trap, produce, concentrate, and recycle abundant nutrients, estuarine areas exceed by several-fold the organic production of our richest farmlands.

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Throughout the world and throughout history, man has been attracted to estuarine situations for the bountiful way in which they provide for his needs and services. On the rich and fertile deltas of the Nile, Tigris, Niger, Po, Rhone, Hwang-ho, Mississippi, Makon and many lesser rivers, great cities have risen, nurtured by the productiveness of the surrounding waters and the lands on which they have been built. The mixing of fresh and saline waters has provided an environment of great biological richness and given man an abundance of fish, shell-fish, waterfowl and fur species with which to satisfy his basic needs. These waters have also served in the transportation of people and goods either inland or coastwise from the population centres they adjoin. The often broad expanses of flat coastal marshlands derived from the silts and sediments carried seaward by the rivers are reclaimed with relative ease and the fertile soils give high yields of agricultural crops. In the early stages of man's exploitation of these lands, his numbers were few and his struggle was to subdue the environment for his own survival. In this he has been eminently successful, so successful in fact, that in many regions he now threatens this environment and as a consequence, that of his own existence.

WILDLIFE VALUES - COASTAL BRITISH COLUMBIA

It has been reckoned that the British Columbia coast has some 170 estuaries. Many of these are small in size but each being of considerable importance to wildlife and more particularly to five species of salmon, together with steelhead and cutthroat trout. The inlets and estuaries taken singly are not extremely productive of waterfowl, (probably because of highly fluctuating water levels, particularly in the breeding season), but some mallards, Canada geese and other species are produced in the inlets each year. In total context however one can visualize a significant production of waterfowl from these areas.

Probably more important than production however is the role played by estuaries as feeding stops in migration. It has been estimated that 4 million waterfowl are in fall migration down the coast of British Columbia. Some use the outside passage but many thousands move down between Vancouver Island and the mainland. Some estimate of numbers has been made for the Fraser Marshes since 1948. Peak numbers occur toward mid-November and aerial counts at that time sometimes run as high as 200,000 ducks and geese. Depending on weather conditions, at least 10% will overwinter in the area. For the most part, these consist of mallards, pintail, widgeon, green-winged teal and snow geese. These are the principal species attracted to the estuary - the diving ducks and other acquatic species being found in the sheltered bays and scattered along the coast. It has been estimated that more than 300,000 snow geese from Arctic Russia (Wrangel Island) migrate down the Pacific Coast of North America to winter in such places as the Fraser estuary, the Skagit River estuary in Washington, interior lakes in Oregon, and the central valleys of California. Arctic Canada's contribution to wintering snow geese on the Pacific is believed to be minimal.

Mild coastal climate encourages waterfowl to spend the winter months in our estuaries. Recent figures indicate that 25% of the world population of trumpeter swans overwinter in the estuaries of Vancouver Island. It is known that many trumpeters winter in the mainland estuaries as well but estimates are not available.

Shorebirds, particularly sandpipers in untold thousands, utilize the coastal mud flats as feeding areas in migration. Dunlin sandpipers, together with thousands of gulls, chiefly glaucous-winged but including new gulls and Bonaparte gulls, overwinter in the warmer estuaries of the province. Great blue herons are found in all our estuaries and at times concentrate in considerable numbers.

The coastal inlets of British Columbia in fall and winter attract the largest remaining segment of bald eagles in North America. When the salmon spawning run is peaking, concentrations of forty to fifty eagles are not uncommon about the estuaries of some coastal rivers.

Grizzly bear, mule deer (coast black-tails), beaver, mink, muskrat, otter and raccoon are all residents of coastal inlets and the harbour seal and sea lion are regular seasonal visitors.

The importance of the marshes for wildlife has long been recognized: their importance as nurseries for fry and fingerling salmon and other fishes is only just coming to light.

HUMAN EXPLOITATION

As rich as estuaries are in resources for man and nature, they can be destroyed by man's activities. Nowhere is competition for environment and associated resources more acute than in our estuarine zone. They are being threatened by population pressures and technological advances. Their fate has been one of steady deterioration and destruction. Relatively few people are completely aware of how man's activities influence the estuarine environment or of the total impact of these activities on the economic and social lives of our people.

Conflicts of interest among uses are common. Major conflicts arise over pollution, logging methods, dredging, and filling of tide flats as pressures for urban and industrial development compete with concern for open space, recreation, and ecological needs. If population growth continues, more demand will be placed on the estuarine environment. With accelerated industrial expansion, greater production and use of power, more shipping in larger vessels, and increasing time for recreation, estuaries and their adjacent coastal areas will be called upon to serve expanding urban needs in many ways.

Perhaps the biggest threats are the filling of tide lands, draining of marshes, and dredging activities which permanently scar and upset the ecological balance of the estuaries. Poor logging, mining and road construction practices in upstream tributaries have caused soil erosion to lands. Consequently, heavy silt loads are deposited annually in estuarine channels and lagoons. To maintain navigation depths and shipping lanes, periodical dredging is required. Not only is the dredging operation sometimes damaging to fish and wildlife habitat, but the improper placing of dredge spoils can be disastrous to these resources. Dredging and spoil deposition are of special concern because of their direct environmental intrusion on fish, wildlife, water, esthetics, and recreational values.

In some instances, estuaries also have been used as sewers for industrial effluents and untreated municipal and boat wastes. Log dumping, booming and storage not only degrades water quality but also usurps highly productive intertidal foreshores. Thermal pollution, too, may be a future danger to the productivity of an estuary.

The human impact on the estuaries of the world has generally followed a basic pattern, although some regional variations may exist. British Columbia offers some classic examples of estuarine use and the problems which are typical in the development and management of this resource.

PROBLEMS ARISING FROM HUMAN IMPACT ON BRITISH COLUMBIA ESTUARIES

1. Fraser River - General

Because of its large size, proximity to high population density and intense industrial activity, man's impact on the Fraser estuary has been greater and more varied than on any other such body in the province.

While man's activities to date have destroyed extensive areas of native habitat on the Fraser, a considerable amount still remains, although constantly threatened. This gradual erosion of habitat is serious in that it is often not recognized until too late.

The Fraser Delta has been the site of sedimentary deposition since the late Cretaceous. Its present annual growth is at the rate of about 28 feet (Holland, 1964). This area of estuarine influence extends from about New Westminster, some 19 miles upstream from the Strait of Georgia, seaward to Sturgeon and Roberts Banks and south and eastwards into Boundary Bay. Within this region the alluvial masses of Lulu, Sea, Westham and other smaller islands have formed, comprising some 130 square miles within the municipalities of Richmond and Delta. These were once large deltaic marshes flooded for almost half of each year. Emerging uplands arose through the formation of the low natural levees and dense, tall grass covered most of the area (Taylor, 1958).

The Fraser River salt marshes are essentially Sturgeon and Roberts Banks. These two comprise some 28,000 acres of intertidal zone of which only a relatively small portion is vegetated. The bulrush, sedge and cattail produce seeds and vegetative roots which are utilized by migratory and wintering waterfowl. Produce of the adjoining farm lands, the most productive in the province, supplement the natural foods of the salt marsh. Increasing urbanization of farm lands has undoubtedly influenced waterfowl numbers and is expected to do more so in the future.

Man's association with the Fraser Delta and estuary is believed to have been established by the Indians many centuries before the coming of the first white explorers. The abundance of fish, wildfowl, shell-fish and other food items supported resident native populations in the Tsawwassen, Musqueam and Marpole areas and seasonally attracted many parties from bands of the San Juan and Gulf Islands and southern Vancouver Island. Indian numbers were relatively few and the nature and intensity of their use of estuary areas was of little consequence to the environment.

In the late 1850's, the first white settlers appeared in the Delta area and took up land along the Fraser River and its many sloughs. The attraction of a location adjacent to a waterway was a factor of some importance in the selection of land and by 1877 much of the river shore and lowlands was acquired by private owners (Taylor, 1958). The availability of water transportation, good soil and low costs of preparing land for cultivation were the primary reasons for the early settlement of these delta lands.

The influence of agricultural development was gradual and involved a continual struggle against flooding and poor drainage. Dyking was begun initially about individual farms a few acres at a time until the heavy flooding of 1894. The results of this catastrophe stimulated development of a co-ordinated dyking program in the Delta municipality in 1895 and by 1896 the main dykes were constructed.

Dyking also progressed in Richmond, the other municipality comprising this estuarine area, and resulted in the present existence of about 43 miles of sea dykes and 29 miles of river dykes protecting some 46,730 acres of land in the two municipalities (Fraser River Joint Advisory Board, 1968).

The initial change of this area was from primitive marsh to reclamation and agriculture. When drained, the fertile soil and moist climate provided good hay and pasturage which in early settlement days supported beef cattle as the main agricultural enterprise. As the human population developed in the greater Vancouver and Delta region, dairying became important in the farm economy and oats, hay and mangles were grown as livestock forage. In 1894 some 10,500 acres were under cultivation in Delta Municipality and in 1941 almost 25,000 acres. By 1951 cultivated acreage had declined to some 21,000 acres.

Over the years the original hay and grain crops remained dominant but new products such as poultry, potatoes, fruit and vegetables began to appear in the late 1920's. Basically, there has been little change in the agricultural crop pattern since those days. There have, however, been many changes in the intensity and methods of agricultural practice which has evolved from the days of hand-operated tools through horse-powered equipment, to the present highly mechanized operation of the modern farm. In spite of the relative physical stability of the lands within the dyked area these changes have been accompanied by developments of some consequence to the quality of the estuarine environment.

The traditional biological richness of estuaries is a well-known quality of the Fraser River which from primitive times has been evident in the annual migration and harvest of salmon. These fish were a major food source for the native inhabitants and were sought by the white man from his first days on the Delta about 1870. By 1880 there were 13 fish canneries on the Lower Fraser River, four of which were in the municipality of Delta. In the latter region, this number had grown to 14 by 1905 and then declined to the present one remaining in operation. Industrial wastes from fish canning, once a source of concern to municipal councils of the 1880's have diminished with the decrease in number of these processing plants but are still present to some degree.

The foregoing example of human activities on the Fraser River Delta illustrates the basic pattern of discovery, reclamation and agrarian development, exploitation of the fishery and the use of the waterways for transportation and commerce typical for such areas throughout the world. Beyond this point civic or community growth reaches a stage at which problems of a socio-economic nature appear to threaten the continued viability of the estuarine resource.

2. Fraser River - Specific Problems

(a) Sewage Treatment

At the northerly end of Sturgeon Bank the City of Vancouver in 1963 opened the Greater Vancouver Iona Sewage Treatment Plant. This is essentially a primary treatment operation but as both waste and storm sewage are accommodated, the 70-80 inch annual rainfall of Vancouver can bring great difficulties in the treating of waste. To cope with this problem a causeway was erected to deflect the effluent out into the deeper water of Georgia Strait. However, as the intertidal area was ditched rather than piped, the result is a flocculation of organic sediment on the salt marsh which continues to build from year to year.

This deposit has detracted from the aesthetic and recreational quality of the area and may in time reduce the use of the area by migratory birds.

(b) Airport Development

Sea Island, on which Vancouver International Airport is located is one of the most attractive areas for birds in the region. However, future airport expansion plans call for reclamation and filling of one square mile of intertidal foreshore. This would virtually eliminate productive habitat in that area.

(c) Navigational Aids

On the remaining Sturgeon Bank Marshes, through man's activities, there are now four radio towers and 13 large wooden navigational markers in the five linear miles of marsh. While not terribly detrimental to wildlife, certainly these structures are inhibiting to the hunter and do nothing to improve the natural quality of the environment.

(d) Recreational Proposal

The 20,000 acres of the waters and shores of Sturgeon Bank were placed under Map Reserve #0240051 by the Provincial Department of Lands and Forests for game conservation purposes. Nevertheless no reference was made to the Provincial Fish and Wildlife Branch when any of the above (c) activities took place. To improve this situation an attempt was made to get the local Municipality of Richmond to request the Provincial Department of Lands to preserve the salt marshes. This action was initiated by the Canadian Wildlife Service plan for recreational development in a narrow area of marsh. The plan incorporated a parallel dyke and development between the dykes for tennis, soccer, golf, riding academy, marina and restaurant. The outer marsh to be left for wildlife and hunting. At that time, it was learned that 600 acres of marsh outside the dyke was privately owned by Crown grant many years ago. The recreation proposal is presently being held in abeyance until the Municipality can establish future plans for the area.

(e) Superport Development

Roberts Bank, some 8,000 acres, is held on provincial Order-in-Council reserve # 2374 for waterfowl purposes. In spite of this, the Roberts Bank

1. Greater Vancouver Sewage & Drainage Board, Iona Island Sewage Plant.
2. Vancouver International Airport, Sea Island.
3. Lulu Island Foreshore.
4. B.C. Waterfowl Society, George C. Reifel Refuge.
5. Roberts Bank Superport.

GREATER VANCOUVER

SCALE IN MILES 0 1 2 3 4

superport was built by the Department of Transport on this foreshore with no reference to its "reserved" status and no rescinding of the Order-in-Council by which it was established.

While some 150 acres of foreshore have now been usurped by the superport, together with 4,000 acres of fertile farmland expropriated for back-up land, wildlife interests were able to recommend anti-pollution procedures and to inhibit the northerly encroachment of the port development on a productive portion of the marsh. A ramification of the expropriation has appeared in the inflation of choice agricultural land to $2,700/acre. Such inflation makes farming uneconomic and opens the door for the speculative developer, at the same time destroying food producing land, which in this province is in short supply. This will affect the thousands of waterfowl that winter in the estuary and depend on the food provided by agricultural crops. With this food source destroyed, how many ducks and geese can our marshes support?

(f) Waterfowl Refuge and Development

The 700 acre sanctuary on the Westham Island foreshore, held under Order-in-Council by the British Columbia Waterfowl Society is a portion of the marsh believed to be sacrosanct. The far-sighted approach to preserving habitat by a private organization is most commendable. Public support generated by the actions of the Society in creating the sanctuary is such that any violation of same would be vehemently opposed.

3. Squamish Estuary

The District Municipality of Squamish, at the head of Howe Sound, encompasses some 40,000 acres of land and has a population of approximately 6,500 people. About 2,000 acres could be classed as productive estuary, most of which was Crown granted in 1916 to the Pacific Great Eastern Railroad (provincial Crown corporation).

The railway's plans for the future call for a bulk loading berth with eight berths on 570 acres of land. Extensive parcels of Pacific Great Eastern land have been leased to Squamish Terminals (100 acres) for two berths, and to Dow Chemicals for a 2 million dollar plant. Plans for coal shipping facilities are not well advanced but extensive coking deposits near Chetwynd and Hudson Hope in the interior of the province lend credibility to the thought that the Pacific Great Eastern will be shipping vast amounts of coal from Squamish within a few years. Pulp, paper, copper, molybdenum and asbestos will also be shipped from these port facilities.

An integral part of the harbour development to date is the building of a training dyke on the east bank of the Squamish River, running a distance of 12,200 feet. Dredging at the mouth of the river itself will take place and this, together with the dyke, will ensure the silt load being carried well out into the bay. The dyke would, of course, serve as a flood control structure as well.

Data on fish and wildlife values in the estuary have recently been assembled. Wildlife values are little understood due to lack of survey data. It is believed that the Delta, chiefly because of severe water fluctuations, has never been important as a waterfowl production area. It has been, however, of some importance as a staging and wintering area. Some waterfowl hunting


PROBLEM AREAS OF SOME MAJOR B.C. ESTUARIES
1. FRASER RIVER ESTUARY
2. SQUAMISH RIVER ESTUARY
3. COWICHAN RIVER ESTUARY
4. NANAIMO RIVER ESTUARY
5. CAMPBELL RIVER ESTUARY
6. QUATSE RIVER ESTUARY (PORT HARDY)
7. SKEENA RIVER ESTUARY (FLORA BANK)
DIXON ENTRANCE
QUEEN CHARLOTTE ISLANDS
Hecate Strait
Limit of continental shelf
Queen Charlotte Sound
Queen Charlotte Sound
BRITISH COLUMBIA
VANCOUVER ISLAND
Strait of Georgia
Juan de Fuca Str.
WASH.
N
0 MILES 100

still takes place but it is minimal. It is appreciated that man's development to date has reduced wildlife values but the extent of reduction cannot be readily measured. Grouse and deer are still present on the alder bottoms but they too are following the general declining trend. Potential habitat is still available with the port site on which wildlife management techniques could be employed providing the unused land could be dedicated to this purpose for at least 20 years.

Data are available on four species of salmon and steelhead trout, all of which spawn in the Squamish River system. Escapement figures are shown in Table I, and commercial values in Table II.

No value has been placed on the sport fishery related to the Squamish River system. However, active river fishing for cohoe and steelhead together with the salt water salmon derbies in Howe Sound and the year-round salt water sport fishery attest to the importance of the system.

What will happen to the commercial and sport fishery after full harbour development can only be conjecture at this point. The recently discovered concentrations of mercury in fish taken in Howe Sound and traced to a local chemical company indicate the need for selection and control of components in future estuarine resource use. Early integrated multiple use would have preserved habitat for at least a portion of the Squamish fish and wildlife populations.

4. Port Hardy

Port Hardy is located on the northeast coast of Vancouver Island on the estuary of the Quatse and Quatesi Rivers. The estuary serves as a wintering home for 25-30 trumpeter swans, as well as Canada geese and ducks. During spring and fall migration, thousands of sandpipers, together with considerable numbers of ducks and geese use the estuary as a feeding and rest stop. More important however, are the rivers an estuary as a spawning nursery area for salmon, crabs, etc. Over 2,000 pleasure boat-days produced a catch of over 20,000 pounds of salmon in the Port Hardy-Alert Bay area during 1970. It is said that this estuary contributes substantially to the perpetuation of salmon stocks which have exceeded 800,000 fish annually, together with numerous trout and tons of shellfish.

The estuary itself is not that extensive but port development plans call for a fill area of 50 acres, together with extensive dredging. It is believed that such activities would constitute a loss of 70% of the highly productive intertidal mud flats.

Stimulus for port development at Port Hardy is the extensive copper deposit presently being mined nearby. Development has presently reached an impasse, until environmental interests can be reconciled.

5. Flora Bank

Active consideration is presently being made for the creation of a deep-water port at the mouth of the Skeena River. Such a development, at the end of the Canadian National Railway's line from Edmonton to Prince Rupert, could handle wheat from the prairies as well as coal, minerals and wood products from interior British Columbia.

TABLE I

11 Year Escapement Average

SPECIES	ESCAPEMENT
Chumn	44,678
Cohoe	21,558
Pink*	253,240
Chinook	18,086
Steelhead	12,281

*Odd year runs only

TABLE II

Value of Commercial Catch for 1970 Based on Squamish River System Production

Species	Escapement	Calculated Catch	Gross Wt. of Catch (lbs)	Wholesale Value Per lb	Wholesale Value of Catch
Chum	100,400	50,000	550,000	43.0¢	$236,000
Pink	24,500	98,000	568,400	49.1¢	279,084
Cohoe	44,000	132,000	805,200	65.2¢	524,990
Chinook	28,075	112,000	1,228,000	79.9¢	981,197
				TOTAL	$2,021,246

This area has an extensive intertidal zone and eelgrass beds. It is of some importance to fishery interests and could be virtually eliminated if proposed development plans are pursued. Deep-water dredging will destroy eelgrass beds and secondary industry, in the form of chemical plants and oil refineries, will pose further threats to ecological aspects of the area.

6. Campbell River

The Campbell River is world famous for its sport fishery. It is the site for a proposed federal fish hatchery. Of present concern to the environment is the use of the area for log booming. This threat promises to become more acute with the proposal for the dredging and filling required to provide for a contemplated marina and housing development.

7. Nanaimo River

The estuary of the Nanaimo River receives extensive use for log storage and is now under consideration for utilization as a major port facility. Some 165 acres of estuary will be dredged and developed with federal funds. The area is a wintering ground for waterfowl on the east coast of Vancouver Island and has further importance for fishery interests.

8. Cowichan River

Also important for its fishery and wildlife value the Cowichan River estuary serves as a major log sorting and storage area. There are suggestions for dredging and filling to accommodate the construction of a sawmill on this estuary.

LEGISLATION AND ADMINISTRATION AFFECTING ESTUARINE MANAGEMENT IN BRITISH COLUMBIA

The protection and management of estuaries in British Columbia does not seem to lack legislative or administrative support. At least 13 federal and 7 provincial acts exist under which numerous agreements, boards and commissions have been established to deal with particular aspects of human use which in some degree affect this type of environment. These include the following:

Federal Acts

Canada Shipping Act

Coastal Fisheries Protection Act

Fish Inspection Act

Fisheries Development Act

Fisheries Act

Navigable Waters Protection Act

Indian Act

Sockeye Salmon Fisheries Convention Act

Government Harbour and Piers Act

Harbours Commissions Act

National Harbours Board Act

Canada Water Act

Migratory Birds Convention Act

Provincial Acts

British Columbia Fisheries Act	British Columbia Land Act
British Columbia Wildlife Act	British Columbia Forestry Act
British Columbia Parks Act	British Columbia Municipal Act
British Columbia Pollution Control Act	

Administrative Bodies

Ministry of Transport	City of New Westminster
Department of Public Works	City of White Rock
Department of National Defence	B.C. Department of Recreation and Conservation
Department of Indian Affairs & Northern Development	B.C. Department of Lands, Forests and Water Resources
Department of the Environment	B.C. Department of Municipal Affairs
Municipality of Delta	B.C. Pollution Control Board
Municipality of Richmond	Regional Districts
Municipality of Surrey	Fraser River Joint Advisory Board
Municipality of Burnaby	International Pacific Salmon Commission
City of Vancouver	
B.C. Harbours Board	

As well as the powers held by administrative groups, there are also certain rights belonging to owners of riparian property in estuarine situations. These rights exist in and upon the water in front of an owner's land even where the land covered by water is vested in someone else and regardless of whether the water is a navigable river, whether tidal or otherwise, or is a portion of the ocean itself (Cunningham, 1971). As explained by Cunningham, these rights provide the riparian owner with access to every part of his frontage at all times, the right to construct protective dykes or embankments and the right to acquire lands which accrete naturally to a bank of his riparian property. Further, the owner is entitled to water in its natural condition in front of his land undiminished in quantity and quality, providing authority is granted by the Commissioner of the District. In British Columbia, this involves the securing of a licence from the Water Rights Branch. In some areas, the riparian owner would, under common law, have the right to erect a wharf or pier in front of his own lands but this is not the case in British Columbia where the new Land Act reserves the bed of all lakes, rivers, streams or other bodies of water unto the Provincial Crown (Cunningham, 1971).

CONTROLLING HUMAN IMPACT ON ESTUARIES

The importance of estuaries in coastal ecology has been recognized by a relatively small minority for some time. In British Columbia, in order to gain support for preserving estuaries a cross-mission Estuary Working Group was created last year under the aegis of the Pacific Region Directors' Committee. Fisheries Service and Research Board, Forestry, Wildlife, Environmental Protection, Water Surveys, Water Planning and Marine Sciences are all represented. The chief raison d'être for the formation of the Group is to obtain support for government action in taking necessary steps to preserve the estuaries.

There is growing awareness of the need for multi-use as opposed to past single-use consideration of estuaries. A single body representing the interests of the total environmental potential is essential to the best future management of this resource. It is equally essential that such a group have the ecological information necessary on which to plan a sound integrated program. This consists of inventory surveys, land-use mapping and land-use planning in co-operation with all levels of government. Minutes of all Working Group meetings go to the Pacific Region Directors' Committee, to branch directors and to the Management Committee. Special funding for this program has not yet been developed.

Land and water use planning is the obvious key to multiple-use development in the estuarine zone. A plan must emphasize protection of natural marine resources while recognizing the need for balanced development of port, industries, recreational facilities and maintenance of an attractive residential environment. The final destiny of our estuaries will be determined by the concern, wisdom and foresight of the people of Canada.

RECOMMENDATIONS

The Department of the Environment should:

1. Provide necessary funds and manpower with which to carry out a resource inventory of major estuaries, together with obtaining land-use data. It is essential to be armed with data before the development proposals are made.

2. Initiate a public education program on the importance of and need for preserving the estuaries, i.e. - reports, film, documentaries, etc.

3. Establish stricter enforcement of present regulations and establish new legislation if necessary to preserve and prevent degradation of the environment.

4. Encourage interdepartmental co-operation in preserving the habitat, particularly in regard to dredging, filling, etc., of intertidal lands.

5. Take the initiative in establishing liaison and co-operation at all levels of government in the administration of estuarine lands.

6. Encourage provincial governments to enact special legislation for preservation of not only estuaries but important shorelines as well. Special funds should be made available to the provinces with which to acquire critical shorelines and estuaries. In some cases it should be possible for government to buy easements, where the owner would retain trespass, hunting and fishing rights but would not sell the rights to alter the marsh in any way.

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ICE PROBLEMS IN THE ARCTIC COASTAL ZONE

O.H. Løken[1]

INTRODUCTION

Two major and partly related developments and subsequent events have greatly changed our assessment of problems related to ice in the coastal zone, particularly in Arctic Canada.

(a) The discovery of large quantities of gas, smaller quantities of oil and the prospect of further exploration, discoveries, and exploitation of these resources.

(b) New legislation passed by Parliament, notably the Arctic Waters Pollution Prevention Act (Bill C-202) and amendments to the Canada Shipping Act (Bill C-2).[2]

Both these developments have implications for the Department of the Environment because we will be responsible for providing much of the technical data and judgments essential for the development of suitable regulations to control future developments in the area. These regulations must be formulated with great care so that future development will proceed with an acceptable level of environmental changes.

Environmental protection, in the context of economic development, is first and foremost a national issue. But, the Arctic Waters Pollution Prevention Act has ramifications outside Canada, because Canada has taken a major step in international law on a unilateral basis. In such cases, it seems advisable for the country in question to be in possession of a maximum of data about the regions concerned, so that objectives of the law can be achieved through effective implementation of practical and realistic regulations.

POTENTIAL ICE PROBLEMS

Possible ice problems have already been outlined by representatives of the oil companies, by scientists and by others. Therefore, the following section does not present particularly new information; however the viewpoint

[1]Inland Waters Branch, Department of the Environment, Ottawa

[2]Bill C-2 has been proclaimed and regulations pursuant to this Act have been issued. Bill C-202, not yet proclaimed, is still taken as an expression of Government thinking in regards to Arctic waters.

is different as the ice problems are considered in the context of the Department of the Environment and its role in coastal zone management. Emphasis is on looking at sea ice as an element of the coastal environment and not, as is usually the case, as an obstruction to shipping.

The coastal area under consideration is rather broadly defined. It includes all of our coastal waters where ice may cause problems (ice in this context may be sea ice or icebergs). The attention is focused, however, on the waters in and around the Arctic Archipelago, the Beaufort Sea coast, Hudson Bay and Hudson Strait, and the eastern seaboard.

While the ice problems are generally experienced close to the shore, partly because on-shore ice pressures usually reach a maximum near the shore, the events which cause them may occur far away. If therefore we seek the causes of particular ice conditions, or try to forecast these conditions, then we must also consider regions located far from our coast; i.e. the central part of the Arctic Ocean as a possible source of events leading to the conditions near the shore. It is, therefore, not practical to define the width of the coastal zone in the context of ice problems.

Ice problems may be encountered in connection with a variety of activities, such as:

Off-shore Oil and Mineral Developments

(a) Exploration

With a major part of the Continental Shelf under lease and exploration drilling already underway off Labrador, it is only a question of time before off-shore exploration drilling will start on a large scale basis.

In order to design suitable platforms, information will be needed on ice movement and ice pressures from areas which have attracted little attention so far, because they were far from existing and potential shipping lanes. In other areas where ice information has been collected, the data obtained are often not of the type now required. Of particular importance will be the production and movement of icebergs or large ice islands, and of the combined effects of ice and waves. Artificial islands to be used as drilling platforms will be built in the Mackenzie Delta area this summer (1972), and similar methods may be used in other locations. Submarine ground ice may also be of importance in such operations, and a better knowledge of its formation and distribution will be needed.

(b) Development and Exploitation

Design criteria will be required for well-head installations, whether bottom or surface-based, so that engineering, construction and operation of wells will be in accordance with all safety regulations demanded by hostile ice conditions.

(c) Pipeline Installations

Gas export from the Arctic will most likely be by pipeline; and many pipeline routes have already been projected across the channels in the Archipelago. This raises several new problems:

(i) In the near-shore area, scouring by the moving 'fast ice' may cause major problems in addition to those caused by icebergs, ice-islands or flows with large multi-year pressure ridges. Shallow depths extend far off shore along some of the island coasts, and problems along the ice-island junction may be specially significant.

(ii) While the laying of pipelines at great depths on the sea floor is now a fairly routine operation in warmer climates, there is little or no experience in colder climates, particularly in northern ice-covered areas where ice may completely prevent pipeline laying for most of the year, and where ice will be present as a potential year-round disruptive factor. Clearly any pipe-laying operation must be carefully planned and will probably be limited to a very short period in any year. The optimum periods for such marine operations will, however, coincide with the period when land-based operations are most restricted.

Contingency Planning

It is unrealistic to expect that accidental spills will not occur and we will be faced with the problem of dealing with oil in ice congested waters. The containment and detection of oil and the monitoring of oil movements under such conditions will pose serious problems.

Harbour Operations

The increased activity of the petroleum industry will result in new demands for the movement of incoming as well as outgoing freight. Some of this will undoubtedly be by air, but most of it will be accommodated by marine transport. New harbour facilities will be needed, and they must be located and constructed in full recognition of the local ice conditions.

Other Problems

(a) Beach Stability

Construction and, at a later stage, the operation of facilities near the shore may significantly change the ice regime (e.g. through thermal pollution) which in turn may influence the available wave energy on the beach and hence the sediment movement. Where the ice content of the beach and the near-shore is high, significant changes in the shoreline stability may occur.

(b) Coastline Changes

Large sections of our Arctic coastline, notably that of Ellesmere Island are formed by glacier fronts, some of which are calving. Glacier fronts are noted for their instability and the locations of these coastal sections are therefore subject to changes. Such changes are significant in a legal as well as in a physical sense. This also applies to ice shelves which form independently of adjacent glaciers, as for example the incipient ice shelf in Nansen Sound.

(c) Arctic Hydrology

Ice conditions in Arctic waters depend on many factors, for example, the rate of supply of fresh water from our major northward flowing streams and the melting of icebergs. Hence, any changes in the regime of Arctic rivers, e.g., the Mackenzie River, should be approached with caution. Hopefully, we may learn much from the proposed James Bay development.

(d) Use of Submarines

The possible use of submarines will raise other ice problems, e.g., the bottom profile of the ice cover and the protection of loading facilities.

FACING THE CHALLENGE

The preceding section has focused on some potential problems which may appear in ice infested coastal zones. Undoubtedly, the list is incomplete, and additional problems will occur. However, in order to provide answers to some of these environmental problems, we must consider the type of information we need and the methods required to obtain it. A suggested series of specific objectives is outlined below, showing some of the practical and scientific questions which require answers.

Ice Pressure

(a) What are the dynamic pressures exerted on structures by the ice during ice runs and how are these related to weather and geographic location?

(b) What is the distribution pattern of pressure ridges?

(c) What are the static and dynamic pressures caused by "fast ice"?

Ice Distribution

(a) Freeze-up and break-up patterns and their dependence on weather and geographical location.

(b) Rate of ice clearance.

(c) What are the implications of possible deliberate action to

i) accelerate the dissipation, or

ii) to stabilize the ice cover?

Studies of the incipient ice shelf in Nansen Sound[3] indicate that management of the ice cover may soon become technically feasible as well as economically practical. Such action will influence the oceanographic regime, the air-sea interaction and the migration of wildlife, to mention but a few, and should not be undertaken without impact studies.

Icebergs

(a) What force is required to make the common bottom scour marks?

(b) How can we predict movement of icebergs? Are there preferred paths? How does the frequency change?

It is suggested that we need to accelerate our ice investigations, particularly in the Arctic, in order to describe and to understand the ice conditions, keeping in mind the type of ice information which is required to meet current and future demands.

Although the objective is different, the type of ice information now needed does not differ very much from what is presently collected largely for shipping purposes. However, the areas to be covered have been expanded, e.g. to areas with semipermanent ice cover within the Arctic Archipelago and to adjacent parts of the Arctic Ocean, and the amount of data to be collected has increased accordingly. The application of remote sensing techniques and new data handling systems will facilitate respectively the acquisition and the processing of the new data.

The need for descriptive information is important, but even greater emphasis should be placed on providing forecasts of ice conditions, and this requires knowledge of the fundamental physical processes that govern the development and behaviour of sea ice. To achieve this, it is suggested that we examine the environmental implications of projects such as; AIDJEX, POLEX,[4] and North Water, and that we, where appropriate participate actively in those aspects of the projects that are of particular interest to Canada.

As most of Canada's coastline is affected by ice, the task that faces us is a large one, and to solve it will require joint action by several government agencies. Active participation by private industry and university scientists will also be needed in first identifying and then investigating the key problems, so that maximum efficiency can be achieved.

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[3] Hattersley-Smith, G. 1970. The Regime of the Ward Hunt Ice Shelf and of the Ice in the Mouth of Nansen Sound, Ellesmere Island. In: Glaciers, proceedings of a Workshop International. pp. 21-22.

[4] AIDJEX - Arctic Ice Dynamics Joint Experiment
POLEX - Polar Experiment

CONCLUDING REMARKS

Closely associated with the problems of ice in the coastal zone is the development of a technology suitable for ice infested waters. Our investigations and studies should involve private industry in order to promote early development of such a technology so that we can cope with our environment in the most effective way. The term environment is here taken in the broadest sense to include the natural, as well as the economic and political environment. The better our technology, the wider will be the range of policy options open to us.

ESTUARY - OCEAN EXCHANGE

R.H. Loucks[1]

INTRODUCTION

The subject, estuary-ocean exchanges will be taken to include the exchanges of water quality parameters, Q, as well as water mass. The main points to be developed are three-fold: (1) There are two modes of exchange - advective and diffusive which may interfere either constructively or destructively. (2) The partition between advective and diffusive exchange may vary between Q's even though the dynamics be common. (3) The variability of exchange dynamics is concentrated in the advective mode.

The first section introduces estuarine dynamics in its two modes neglecting complicating factors such as Coriolus- and geomorphologically-induced flow asymmetries. The second section develops points (1) and (2). The third section is an attempt to predict future developments, mainly on descriptors of variability in exchange rates due to changing run-off rates and winds.

ESTUARINE DYNAMICS

The history of estuarine dynamics is well reviewed by Gadé (1970 MS) and in Lauff (1967). It is salient to mention that this history is well interspersed with Canadian contributions.

Tides, fresh-water run-off and winds are the important factors in driving estuarine currents. Tidal currents set up shears which induce mixing. Horizontal shears and mixing cause estuary water to be carried seaward on the ebb and to be replaced by seawater on the flood. This we call the (tidal) diffusive mode exchange. Vertical shears cause the river water to be mixed down into the more dense salt water. The resulting pressure field drives a two-layer residual circulation, seaward in the upper layer and landward below (Figure 1).

Fresh-water run-off is crucial to the two-layer residual circulation (advection) described above. The effect of run-off may be amplified by mixing so that the residual transports in each layer amount to ten or twenty times the river discharge. These transports are partially stabilized against short-term variations in run-off but do reflect longer-term variations in both run-off and tidal (mixing) energy (Bowden, 1971).

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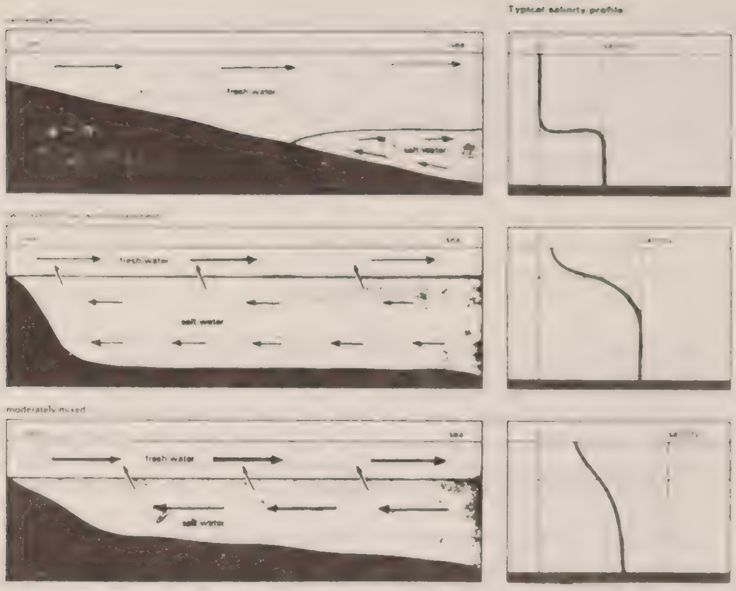
[1] Bedford Institute, Dartmouth, Nova Scotia.



DEGREES OF MIXING of salt and fresh water in an estuary can vary from completely stratified to completely mixed. Diagrams above show three ideal types of mixing and the corresponding salinity profiles. Mixing depends on the strength of the tidal currents relative to the river flow, with the salt wedge estuary occurring in the absence of tidal currents, and can change with the seasons, with the state of the tides or from interference by man.

Fig. 1

Taken from H. and A.E. Rasmussen (1970) in Science Journal 6, p. 37.

The winds as well as the river discharge and tides influence this two-layer residual circulation which constitutes the advective mode of exchange. The landward moving lower layer advective current may be influential in the formation of bars and entrapment of nutrients (Tilley and Dawson, 1971).

Traditionally, advective transport of salt and water has been inferred using the Knudsen relation (Proudman, 1953 and Bowden, 1967). Only the salinity profile and fresh-water run-off were required for this prediction. Alternatively the diffusive exchange of salt has been studied by Stommel in Bowden (1967) and Ippen and Harleman (1961) have used an augmented diffusion coefficient to lump both diffusive and advective exchanges of salt. This approach has been extended by Di Toro (1969) through the concept of mixing for maximum entropy (which is not yet well understood).

In a series of papers, Hansen and Rattray (1962, 1965, 1966) have rationalized the two approaches described above. They propose an estuary classification scheme requiring both (tidally-averaged) salinity and velocity profiles. Their work may be summarized by their stratification-circulation diagram, Figure 2, where the ordinate variable is the ratio of the salinity increment to the average salinity through the column and the abscissa variable is the ratio of the surface residual speed to the integral mean speed. (The latter is the run-off rate divided by the estuary's cross-sectional area.) The parameter, ν_s, reflects the partition between advective and diffusive upstream flux of salt. It is the ratio of the diffusive over the total. Hansen and Rattray (1966) point out that even where stratification is high, the salt exchange may be mainly diffusive and imply that a correction factor is required in the Knudsen relation. Conversely, the advective mode can be dominant even where stratification is slight. Their model permits classification of salt exchange from readily available bulk parameters. Corroborative field measurements are becoming available (Bowden, 1971).

ESTIMATING Q EXCHANGE

If the estuary classification i.e., $\frac{\delta S}{S_o}$ and ν_s is established, then it is possible to derive the magnitude of two-layered advective transport. (The derivation will appear in a paper now being prepared.) These values together with the tidal prism volume and river discharge provide all required transports for an estuary box-model. The addition of information on Q distributions permits calculation of diffusive and advective exchange (Keeling and Bolin, 1967). Ideally then, an estuary cross-section can be classified using readily available bulk parameters, the advective and tidal transports can be inferred and the Q-exchanges, calculated. These Q-exchanges are useful for gauging either source strengths or flushing characteristics. Some results are listed in Table 1 for Halifax Narrows. These may be elucidated through examination of Figure 3. This figure shows the various possible configurations of the gradient of Q and the consequent advective and diffusive exchange. For example, if $\frac{\partial Q}{\partial X}$ is positive toward the head of the estuary and $\frac{\partial Q}{\partial Z}$ is positive upward, then both the diffusive and advective models interfere constructively to produce export (-) of Q. That is, the ebbing and the seaward flowing upper-layer-waters are enriched in the exporting Q. However there are quadrants (Figure 3) and natural examples (Table 1 Coliforms) where the two modes interfere destructively. Because of this possibility, the Hansen-Rattray scheme is tentatively considered to be more fruitful for Q-exchange

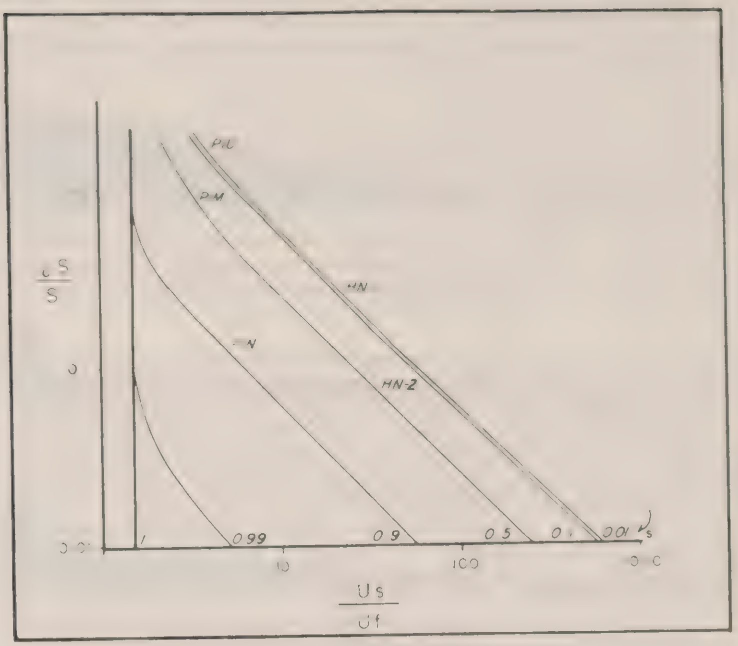


Fig. 2

Stratification-Circulation Diagram (after Hansen and Rattray, 1966.) including results from Halifax and Petpeswick Inlets, Nova Scotia.

LEGEND:

HN-1 Halifax Narrows (6 kms. from head), April 2, 1970.
River Discharge - 13 m^3/sec.

HN-2 Halifax Narrows (6 kms. from head), June 1-2, 1970.
River Discharge - 5 m^3/sec.

PIU Petpeswick Inlet (1 km. from head), August 18, 1971.
River Discharge - 11 m^3/sec.

PIM Petpeswick Inlet (3 kms. from head), August 18, 1971.
River Discharge - 11 m^3/sec.

PIN Petpeswick Inlet (4 kms. from head), August 18, 1971.
River Discharge - 11 m^3/sec.

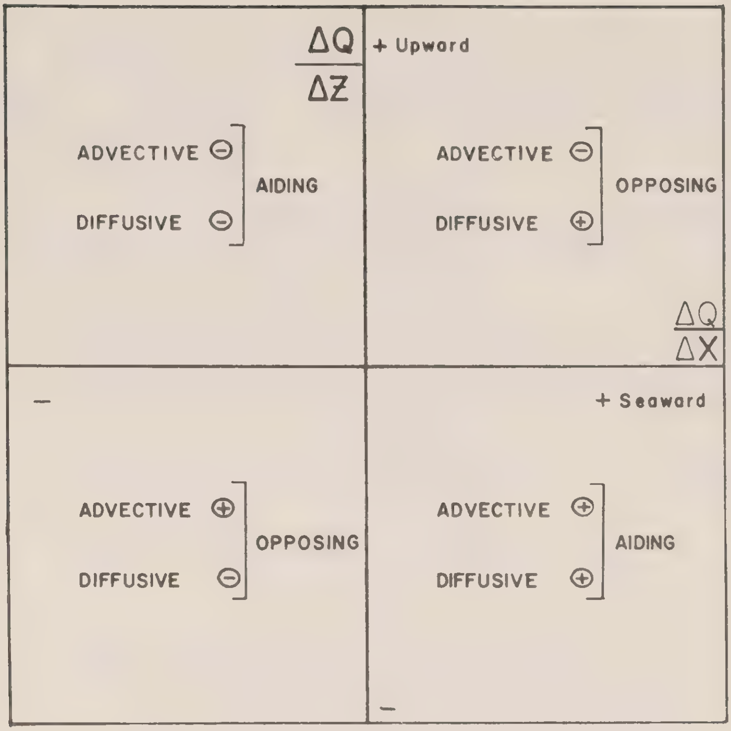


Fig. 3

Relation of water quality parameter gradients to advective and diffusive exchange were (+) indicates input and (-) indicates export of Q.

Table 1. The exchanges of various water quality parameters on two occasions in Halifax Narrows.

WATER QUALITY PARAMETERS	DATE		EXCHANGE (+) IMPORT (-) EXPORT	
			ADVECTIVE	DIFFUSIVE
FRESH WATER ($10^5 m^3$/hr.)	01/04/70 01/06/70		-1.4 -0.2	+.3 -0.05
PHYTOPLANKTON BIOMASS (10^5mg./hr.)	01/04/70 01/06/70		+63.9 -16.6	+23.4 -26.2
COLIFORMS (10^{11}mfc/hr.)	01/04/70		-69.5	+106.8
TEMPERATURE (10^{11}g.cal/hr.)	01/04/70 01/06/70		-13.5 -14.0	-3.6 -4.9
SALINITY (10^5Kg./hr.)	01/04/70 01/06/70		+21.9 -0.9	-8.5 +1.8

evaluation than the Ippen and Harleman technique which lumps diffusive and advective exchange of salt additively.

In summary, the two modes of exchange may interfere constructively or destructively and the partition between advective and diffusive exchange varies between Q's (unless the gradients are identical) even though the dynamics be common. Results are offered which elucidate either source strengths of flushing characteristics. A stringent test of the scheme, not yet made, would be in the study of sediment transport where small variations in water speed assume significance for scouring.

POSSIBLE FUTURE DEVELOPMENTS

Two possible future developments are the definition of an "estuary characteristic" and its utilization in describing the variability in exchange modes and rates.

From the work of Hansen and Rattray, we seem close to being able to define an "estuary characteristic" as a line on the stratification-circulation diagram representing the locus of the classification point as one progresses seaward from the head of the estuary (Figure 4). This line would be expected to shift toward higher ν_s (diffusive) with progress seaward.

With respect to variability, examination of the Hansen and Rattray (1965, 1966) model indicates that variation in fresh-water run-off causes a shift along the "characteristic" while variation in wind stress causes shift

approximately perpendicular to the "characteristic". Thus it is envisaged (Figure 4) that a family of characteristics, each corresponding to a given wind condition, may be constructed to summarize the estuary's dynamics. This eventuality will mesh well with a new technique for summarizing wind data according to magnitude, duration and probability of occurrence. (A probabilistic format is also anticipated for water quality standards in the near future.) In this respect, a diagram such as Figure 4 should be helpful. The figure points up an advantage of analysis for partitioned Q-exchange; because the winds and run-off are quite variable from day to day compared to the tides and because they are most influential with respect to the advective mode, the variability of exchange dynamics is concentrated in that mode. If in a given exchange situation, the diffusive mode is found to dominate, exchange capability will be maintained consistently and nearly independently of variations in run-off or winds.

The above scheme for analysis of estuary-ocean exchange, when applied to pollution situations, would complement the bioassay (indicator species) technique monitoring water quality. Where the latter is extensive in temporal coverage and descriptive, the former is intensive and predictive.

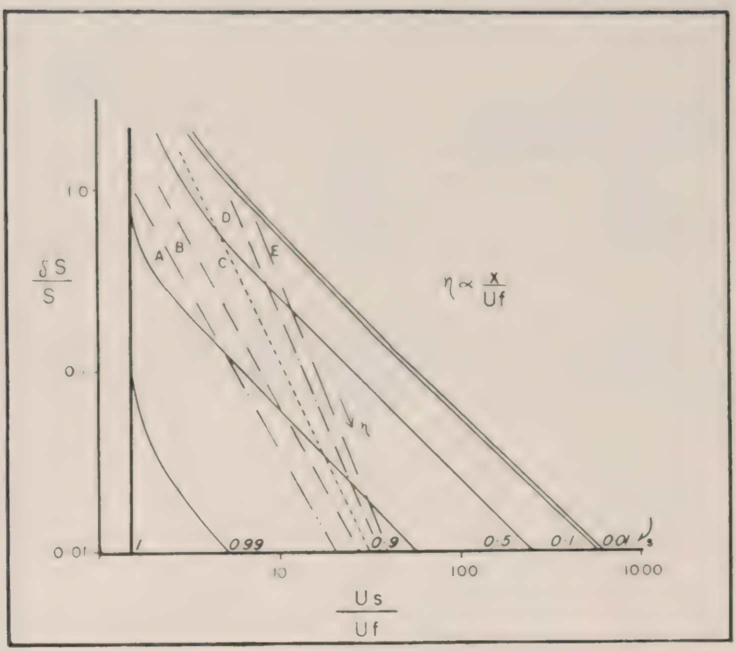


Fig. 4

The family of hypothetical "estuary characteristics" generated by various wind stresses, τ, with their percentage frequencies of occurrence. ($\tau > 0$ represents wind stress directed seaward)

LEGEND:

A - τ = -.1 dynes/cm^2 (5%)
B - τ = -.05 dynes/cm^2 (10%)
C - τ = 0 dynes/cm^2 (50%)
D - τ = +.05 dynes/cm^2 (10%)
E - τ = +.1 dynes/cm^2 (5%)

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THE COASTAL ZONE AND THE OIL POLLUTION THREAT

C.S. MASON *

INTRODUCTION

Pollution of the coastal zone by crude oil and derivates of crude oil is a serious threat and is recognized by the public as a major environmental problem. The problem is very real. In the United States alone the output of petroleum products at refineries increased from approximately 100 x 10^6 million tons to 600 x 10^6 metric tons from 1934 to 1968.[1] The world production of crude oil is now about 1800 x 10^6 tons per annum.[2] Between 1960 and 1970 the amount of oil in transit at sea has increased threefold to about 900 x 10^6 metric tons per annum; between 1966 and 1970 the dead weight tonnage of the largest tanker afloat doubled to 326,000 dead weight tons.[3] In 1970 and 1971, 298 tankers accounting for 41 x 10^6 dwt were scheduled for delivery. This two years output is the equivalent of 2300 *Arrows* of Chedabucto Bay 'fame'.[4] In 1969 20% of the world output of crude oil came from offshore oil fields[5] and there is an impending and continuing offshore boom because of the growing need for energy throughout the world. Currently there are about 50 offshore drilling rigs under construction; most of these rigs are designed to carry the search into deeper and rougher waters. The owners of one of the semi-submarine rigs are planning to drill in 2000 metres of water.[5]

As a result of all these activities there is a continuous loss of oil into the environment, which Blumer[6] has estimated as between 5 and 10 million tons annually. Much comes from discharges from ships, undersea installations, drainage from land sources etc. Indeed 2.5 million tons of waste oil is dumped onto the ground or into sewers in the United States annually.[7] Thus there is a danger of chronic oil pollution to the marine environment and the possible consequences of this gradual but continual introduction of oil are unknown.[4] The Bedford Institute has established programs in both the Pollution Research Laboratory, MEL, and the Chemical Oceanography Division, AOL, which we hope will lead to greater knowledge on which to evaluate the threat of the continuing introduction of oil into the environment from a variety of sources.

The immediate threat of oil pollution to the coastal zone is more obvious and comes from the large and small spills of oil which foul the

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shoreline, kill birds, and may do extensive ecological damage in the inter-tidal zone, salt marshes, etc. [8,9,10,11] The *Torrey Canyon* alone lost 100,000 tons; between 10% and 20% of oil that is loosed at sea is lost in these major spills and much of the oil lost in this manner is carried ashore. In addition to serious contamination from such major events there are some areas of shoreline which are chronically polluted by large tarry lumps up to 6 inches in diameter; the beaches of Bermuda and of southwest England are well known examples of this problem.

In the Arctic and on our eastern and western seaboard, Canada is faced with an increasing threat of major oil losses at sea. The threat is well known. Oil may be transported from Port Valdez to west coast ports in supertankers of 300,000 dwt or greater. Oil fields may be open in our Arctic regions and the demand for other mineral resources such as the rich iron ore of northern Baffin Island will lead to increased marine transport through the Arctic and a consequent risk of oil pollution from fuel in transit. On the east coast we have major oil transfer/refinery facilities developing at Chedabucto Bay, Come-by-Chance, and Lorneville and the almost certain development of offshore oilfields.

Throughout the world we will probably not see an order of magnitude increase in the quantity of oil transported at sea. However, there has been a very significant increase in the past ten years, this level will be maintained and increased. The immediate threat of oil spills to the Canadian coastal zone is going to rise sharply in the next decade; it is necessary to examine the effects of spills and review what we need to do to reduce the damage.

Chedabucto Bay - Then and Now

In February 1970, when the *Arrow* hit Cerberus Rock we had a situation equivalent to that of a three-alarm fire - either respond effectively in a short time (one or two days) - or the damage is done. Quick response was not possible, indeed over two weeks had elapsed before a task force with real authority was established.

Ultimately the scientific studies showed no significant ecological damage[9]; however, there was a heavy coating of oil along the shoreline. Even by the end of February a stable situation on the shoreline had not been reached. A comparison of the extent of oiling between the end of February and mid-summer shows that natural forces had cleaned many exposed areas (Figures 1 and 2). However, oil trapped beneath snow and ice had oiled new lengths of the coastline untouched during the first month.

Throughout the summer of 1970 the more important public recreation beaches were cleaned mechanically. Considerable improvement was achieved although none of the cleaned beaches were suitable for tourist use for that season. It proved to be impossible, with the equipment available, to completely remove all the oil material from the small, steeply-sloped pocket beaches typical of the area. [9,13] Also large sections of cleaned beach were re-oiled when a high tide reached oil-covered pools of water trapped above the normal tide level and the oil was moved to the adjacent cleaned beach. These pools were trapped in rocky areas and the mobile oil continued to flow slowly off the rocks throughout the summer.

The area is slowly recovering. Weathering of the oil on bedrock since 1970 has stabilized the oil to a large extent and it is being continually removed by mechanical erosion and bacterial degradation.

Figure 1. Extent of Oiled Shoreline, February 28, 1970.

Figure 2. Extent of Oiled Shoreline, June 1970 (after Owen).

Winter storms have reworked the beaches and the exposed areas of sand and gravel are now largely clean. However, in some areas considerable oil remains and a clean surface on an inactive beach does not mean no oil.

In Chedabucto Bay we were fortunate. Although there were large bird kills, there was no serious ecological damage, and the beaches of the area were not an important recreational resource. The spill did provide invaluable practical experience - devices such as the 'slick licker' are now field-proven equipment. A continuing scientific study program is providing a history of the spill on which to base quantitative assessments of any future oil pollution of the coastal zone.

Since the *Arrow*, there have been many other accidents resulting in the loss of oil. Eleven other spills in Canada alone came to the direct attention of the Operation Oil Task Force during the active period between February and September 1970. These included spills from tank farms, an oil pipeline, a coastal ferry and a barge. A second spill from the barge *Whale* in September was the greatest threat. Although possibly as much as one-third of the cargo of the *Whale* may have been lost, the oil was mostly dispersed at sea and large quantities did not get into the marshy areas of eastern New Brunswick nor on the PEI beaches. If the PEI beaches were to be as heavily oiled as Chedabucto Bay it would result in serious damage to the major recreational resource of the Maritimes. In spring and autumn the New Brunswick marshes are a stopping point on a major bird migration route and long term damage to a number of species would result from oiling. Blumer has reported serious ecological damage as a result of a spill of diesel fuel in Falmouth Bay.[8]

Will Things Improve?

There is increasing international action to reduce the amount of oil entering the environment. The Intergovernmental Maritime Consultative Organization amended the International Oil Pollution Convention in 1969 to introduce universal use of load-on-top procedures in the world tanker fleet, and there is other concerted international action.[16] NATO nations have resolved to eliminate intentional discharges of oil and oily wastes into the sea by 1980.[17]

In 1971 The Canadian Parliament amended Part 7A of the Canada Shipping Act to introduce much stiffer oil pollution prevention regulations and new Arctic shipping pollution prevention regulations have been drafted.[18] There is a major technological drive, particularly in the United States, to develop new equipment and techniques for spill control and clean-up. There is, however, no known technology to control oil spilt under open sea conditions. If the *Arrow* or *Whale* were to spill oil under the same circumstances as occurred in 1970, we could not control the oil spilt on the sea and prevent it reaching adjacent shores. United States sources have estimated one major tanker disaster will occur annually from 1975 onwards.

What Can We Do?

I do not believe that because we have a coastal zone seminar and an oil pollution problem that general coastal zone studies should therefore be supported. Specific problems should be met by a specific solution.

Volumes I and II[18] of the Operation Oil report contain a series of recommendations, based on experience from the *Arrow* wreck.

One of the more important recommendations of Volume II was:

> "The experience of "Operation Oil" has underlined the vital need for a permanent evaluation unit within the agency designated to be responsible for dealing with spills of oil and other hazardous materials on seas, lakes and rivers. The unit would provide focus, coordination and planning for a national program of research, development and evaluation aimed at improving the techniques of contending with future incidents. Extensive work related to oil spills is underway in Canada and elsewhere in the world, notably in the United States, United Kingdom and Western Europe. The unit would be in close touch with the practitioners of the work and well informed about the growing fund of knowledge and associated system developments with a view to selective adaptation to the Canadian situation. It would promote and arrange for the conduct of research and development in Canadian universities, government laboratories or industry. This would be a selective program centred on those aspects of the general problem in which Canada is or should be particularly expert -- oil spills in ice-infested waters are an outstanding example. A staff of 3 to 4 professionals (engineers and scientists) is suggested as appropriate for a program of this breadth."

A start at forming such a group has been made with the establishment of an Oil Pollution Officer in the Ministry of Transport.[19] However, Stuart's group have an operational mandate only and no single group either within MOT or DOE is responsible for coordinating research, design, and development as suggested in Volume II.

Thus there is no coordination of effort* although some programs have been established - i.e. the technical work at CCIW on booms, filters, etc., and the BI program to study the fate of oil at sea. I recommend that we reconsider the recommendation of Operation Oil and that the small group outlined be established in DOE to work in close communication with Captain Stuart and his staff in MOT.

Without such a mission-oriented group with a clear mandate I do not think we will develop and implement the necessary technical advances to significantly protect our coastal zone from the increasing incidence of oil pollution.

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*(Recommendations of the Oil Pollution Workshop (Nova Scotia Technical College, August 1971) have been forwarded to the Scientific Coordinator for Operation Oil. However, several of the recommendations relate to work not already underway and we know of no agency to whom they should be forwarded for consideration. The recommendations are reproducted as Annex I to this paper.)

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ANNEX I

RECOMMENDATIONS OF THE OIL POLLUTION WORKSHOP, AUGUST 1971

Oil Pollution Workshop 1971, sponsored jointly by the Atlantic Oceanographic Laboratory, Department of the Environment, and the Chemical Engineering Department of the Nova Scotia Technical College, was held at the Nova Scotia Technical College on August 26 and 27th, 1971.

The purpose of the Workshop was twofold; to provide an opportunity to summarize results of projects relating to the *Arrow* incident which had not been completed at the time of writing of the reports of the Federal Task Force to the Minister of Transport, and also to provide a forum for the interchange of information for people in the Maritime area who are concerned with oil pollution problems whether they were involved in the *Arrow* incident or not.

As the Workshop progressed it became apparent that the oil spill in Chedabucto Bay will have long-lasting effects on both the ecology of the area and the physical environment. There are many unanswered questions pertaining both to the ultimate fate of the oil and to its effect upon the environment. It is clear that continuation of the studies which were initiated following the wreck of the *Arrow* can provide information of great value in dealing with marine oil spills; information which cannot readily be obtained elswhere.

As a result of these considerations the Workshop in its final session agreed to the following recommendations.

1. In view of the fact that new biological effects have been observed this year the studies of the biological consequences of the oil spill in Chedabucto Bay should be continued.

2. In view of promising preliminary results on biodegradation, work on this should be continued and expanded.

3. A study of the present distribution and redistribution of oil in Chedabucto Bay should be carried out. This should include a study of the bottom sediment in Chedabucto Bay.

4. The program of the assessment of natural cleaning of Chedabucto Bay should be continued.

5. In view of the fact that the process of weathering is still obsecure, and in view of the importance of the process on clean-up technology, greater effort should be made to investigate the mechanism of the various processes which cause weathering.

6. Inventories of coastal environments should be undertaken in areas where the possiblity of oil pollution is high. These interdisciplinary studies should include an evaluation of the wildlife, biological, oceanographic, geological and economic factors in each area.

7. Effort should be expended on development of improved methods of mechanical cleaning of beaches.

8. Development of better analytical methods of identification of the presence and quantity of oil should be pursued.

9. Efforts to develop methods of identifying the origin of samples of oil pollutants should be continued.

10. A systematic approach should be undertaken to determine more accurately the total amount of oil on the high seas.

THE SEA STATE AND THE 'DESIGN WAVE' DISTRIBUTION ALONG THE CANADIAN ATLANTIC COAST

H.J.A. Neu[1]

ABSTRACT

The sea state along the Canadian Atlantic Coast and over the Continental Shelf has been analyzed with respect to time and space for the year 1970. The methods applicable to developing such a wave climate and the concepts utilized are briefly reviewed. The results are presented in bimonthly nondirectional energy distributions, representative samples of directional energy spectra and wave statistics, and in a distribution chart containing the statistically derived 'design wave' (100-year wave) for the Canadian Atlantic Coast.

INTRODUCTION

In recent years oil exploration has greatly increased along the Canadian Atlantic Coast and over its Continental Shelf. All available exploration permits have been acquired and several oil rigs and ships are drilling on the Nova Scotian Shelf, on the Grand Banks and on the Labrador Shelf.

This exploration is faced with exceptional technological problems with regard to the aquatic environment, especially the sea state. As in other coastal areas, the available wave information was insufficient for the design of structures, safety standards and planning of off-shore operations. A solution therefore had to be found to provide the required information, particularly with respect to the seasonal occurrence and distribution of extreme wave heights along the seaboard.

The investigation covers the off-shore region from the Gulf of Maine to Hudson Strait and seaward to the 2000-metre depth contour (Fig. 1). The depth over the Continental Shelf is generally between 75 metres and 250 metres except for some shallower areas on Georges Bank, around Sable Island and on the south tip of the Grand Banks, where depths are less than 50 metres. Thus, over most of the Shelf, with the exception of the near-shore region and in the shallow areas mentioned, the waves propagate as 'deep water' waves, their motion being unaffected by the bottom topography.

WAVE OBSERVATION METHODS

There are four methods of obtaining sea state data. They are: hind-casting from wind observations, direct measurement with wave gauges, aerial surveying and visual observations from ships.

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Figure 1. Canadian Atlantic Coast and Continental Shelf.

Hindcasting has been applied extensively in the past. Its shortcomings, however, lie primarily in the fact that insufficient meteorological observations are made over the open ocean, particularly with respect to varying winds and moving fetches and that the generation or decay of waves in response to these winds is inadequately understood.

Direct surveying with wave gauges appears to be the most logical method, yet it is confronted with extreme difficulties. The transmission range of radio signals is about 15 to 20 km for conventional automatic equipment while the Shelf is 200 to 500 km wide. Waves observed within this near-shore zone are usually influenced by shoaling and refraction. The conversion to a deep-water wave climate using the refraction principle is possible only when the directions of the waves are known. These directions could be obtained reliably only with groups of gauges. Furthermore, wave gauges, exposed to the hazards of the open sea, usually have only short operational lives. For time series presentation and probability of occurrence, pairs (or groups) of gauges would have to be placed at each location to ensure a continuous yearly record. For direct wave height and energy comparisons along the coast and on the Continental Shelf, hundreds of such groups would have to be operational for years. This would be a monumental task for installation and maintenance, without considering the data processing problem.

The third and potentially the most promising method of obtaining wave data is that of surveying from aircraft or satellite. Although some success has been achieved from aircraft, large-scale application of the method does not appear to be available for at least a decade.

For this study, the data were obtained primarily by visual observations from ships. Some information was derived from the wave gauges on the oil exploration rigs. Twice daily, the wave and weather observations of 30 to 40 stations consisting of weather ships, Canadian and U.S. Government and Navy ships, merchant ships and oil rigs, are obtained by the Maritime Forces Weather Centre. Here, the data are reviewed on a 24-hour basis, and related continuously to the preceding and present wave and wind environment by meteorologically trained personnel. Information which does not fit into the developing pattern is checked for errors in observing, reporting or communication and, if found faulty, discarded. By this process, the wave data are subjected to a large measure of quality control. The data are then plotted on charts and lines of equal wave height are drawn. The resultant information is issued twice daily.

It has been stated by Wiegel (1964) and Ippen (1966) that wave properties obtained by visual observations are equivalent, for practical purposes, to those defined as 'significant waves'; the height (H_{sig}) being the mean height of the highest third of all the waves in a wave train. The sampling period decided upon for this investigation was six hours; that is, the significant wave used was considered to be representative of the sea state for a six-hour time interval. The maximum wave height (H_{max}) is related to the significant wave height in a Rayleigh relationship. According to Wiegel (1964), Ippen (1966), and Thom (1971), the ratio between the extreme wave heights and the significant wave height can be assumed to be about 1.8:1 for a recording period of six hours.

In coastal and off-shore operations, longer term maximum wave heights such as the 10- or 100-year maximum are of utmost importance. These long-term maxima are obtained statistically as described by Draper (1963). The

maximum wave heights of each six-hour period for the entire year 1970 were plotted on probability paper against percentage exceedance. An extrapolation of the line fitting these points indicates the maximum wave heights which will probably occur in the respective periods.

To evaluate the energy distribution and its seasonal and directional variations along the coast and over the Shelf, the energy of the six-hourly significant wave was calculated. The energy per wavelength and per unit width of wave crest in the m-to-sec system is given by:

$$E = \frac{1}{8} \gamma H_{sig}^2 \cdot \lambda \text{ (m ton/m)}$$

where γ is the specific weight of sea water, approximately 1.025 (ton/m^3) and λ is the wavelength (1.56 T^2 (m) in deep water, where T is the wave period in seconds). The number of waves which occur over a six-hour period is: n = 6.3600/T, thus, the total energy per metre of wave crest for an interval of six hours is:

$$E_n = 4.32 \cdot 10^3 \cdot H_{sig}^2 \cdot T \text{ (m ton/m)}$$

RESULTS

The results are presented as follows:

(a) Bimonthly nondirectional energy distribution for the entire region (Fig. 2);

(b) Three representative samples of monthly directional energy spectra, the first for the region off Labrador Coast, the second for the outer region of Grand Banks, and the third for Scotian Shelf (Fig. 3);

(c) Monthly directional wave statistics of the above second and third representative samples (Fig. 4);

(d) Long-term, i.e. 10- and 100-year most probable maximum wave height for selected areas (Fig. 5);

(e) 'Design wave' (100-year maximum wave height) distribution along the coast and over the Shelf (Fig. 6).

CONCLUSION

The results shown in Figures 2, 3 and 4 demonstrate clearly that the sea state along the coast was highly non-uniform with respect to time and space. During the winter, the monthly energy level was approximately five times greater than during the summer. Energy concentration on the Grand Banks and along the coast of Labrador was three to four times that over the Scotian Shelf. The reason for this lies in the seasonal variation of the direction and strength of the wind. During the winter, strong north-west winds are off-shore relative to the southern coast thereby reducing the sea state by opposing the mid-Atlantic waves, and are parallel to the eastern seaboard where they generate large seas along the coast of Labrador and over Grand Banks. During the summer, winds are primarily from southwest along the southern coast and away from the eastern seaboard. Since these winds are light, wave action along both coastlines is very low.

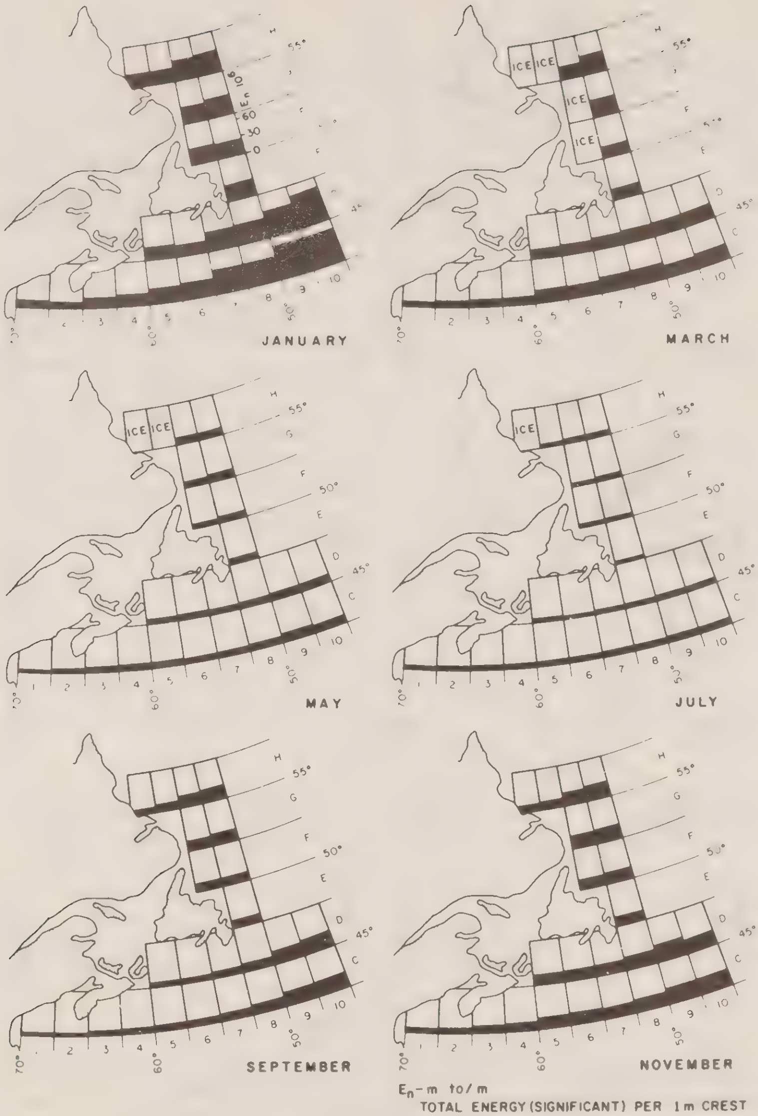

Figure 2. Bimonthly Nondirectional Energy Spectra.

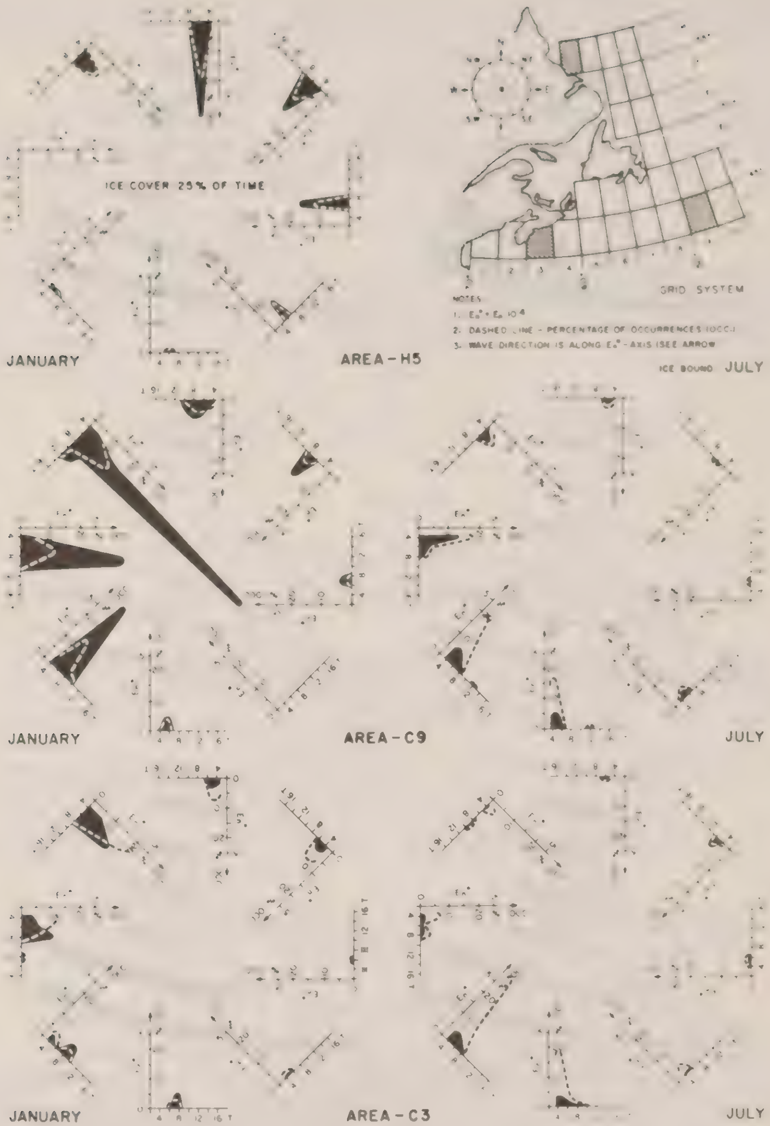

Figure 3. Samples of Monthly Directional Energy Spectra.

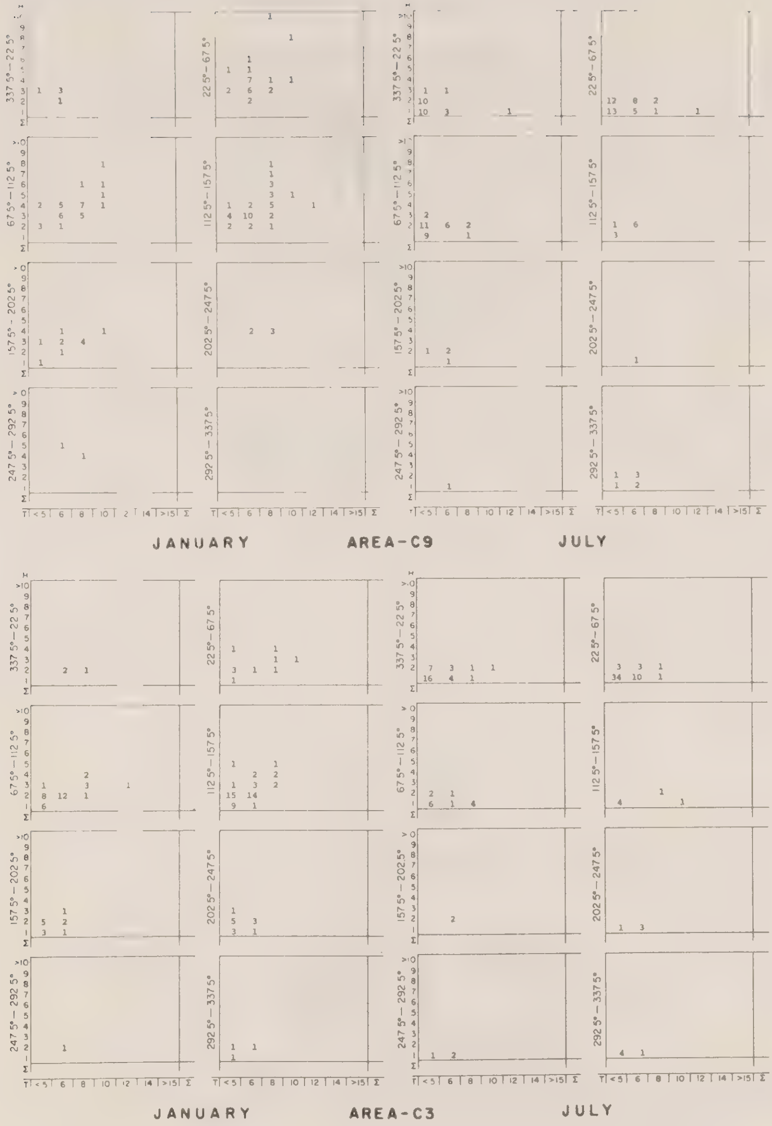

Figure 4. Samples of Directional Wave Statistics.

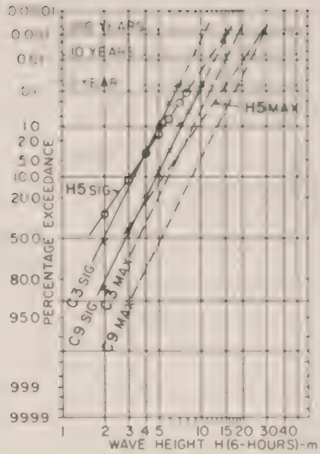

Figure 5. Long-term Significant and Maximum Wave Height Prediction.

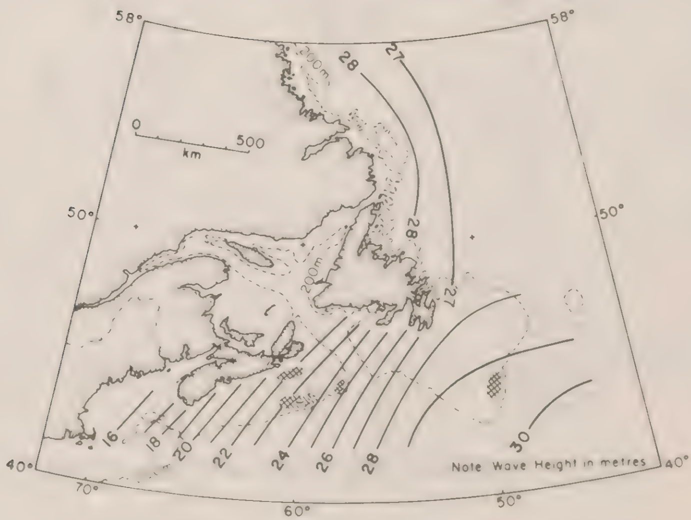

Figure 6. 'Design Wave' (100-year Wave) Distribution.

In 1970 extreme wave heights over Scotian Shelf were in the order of 12.5 metres, while over Grand Banks they reached 19 metres.

In designing oil rigs the 'lifetime' or 'design-wave' is usually the 100-year wave. Its height, as shown on Figure 6, varies from 16 metres (52 feet) in the Gulf of Maine at the U.S.-Canada border to 30 metres (98 feet) at the outer region of Grand Banks. Along the eastern coast of Newfoundland and the Labrador Coast the height of the design wave is quite constant and almost of the same magnitude as over Grand Banks. The shaded areas on Figure 6 indicate that in these regions the height of the 'design wave' may be still greater than designated, due to shoaling and refraction.

Extreme value statistics were also applied to obtain long-term maximum wave periods. It was surprising to find that the maximum 100-year significant wave period, in the order of 20 seconds, was very much the same along the entire coast. No attempt was made to relate this period to the absolute maximum wave period.

From these results, the conclusion must be drawn that a drilling rig which has been built for a 'design wave' of, say, 20 metres may withstand successfully all sea conditions on Scotian Shelf, but would probably fail over Grand Banks or off the Labrador Coast.

ACKNOWLEDGEMENT

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DIRECTIONS FOR THE FUTURE IN MARINE CHEMISTRY

Alan Walton[1]

INTRODUCTION

It gives me considerable pleasure to address this gathering called to discuss some of the most immediate problems confronting the Department of the Environment in a most crucial area related to Canada's future well-being – the coastal zone. My personal pleasure is derived in three ways. First, the occasion presents an opportunity to inform colleagues in the Department of the raison d'être of the Chemical Oceanography Division in the Bedford Institute. Second, it gives me the opportunity to outline the objectives of the Division within the context of the overall aims and objectives of the Department. Third, and not necessarily in this order of importance, it is a fitting occasion to make some suggestions as to the part to be played in the future by marine chemistry, particularly as we orient ourselves to cope with the environmental problems of our coastal areas. My proposals and suggestions may be considered by some as being presumptuous but I trust that they will be accepted in the spirit in which they are offered - as constructive suggestions to be considered objectively by all those concerned with the management of one of Canada's major assets - its shorelines and their immediate environs.

MARINE CHEMISTRY IN CANADA

1. The Past

The past of marine chemistry in Canada is undoubtedly grim and perhaps one should not dwell too long on the subject. Nevertheless, its development bears examination because it indicates some of the current problems and thus the need for immediate remedial action.

As far as marine studies are concerned Canada has been traditionally strong in the biological sciences. Interest in chemical and physical studies were largely ancillary to the biological requirements prior to the 1960's and little need was seen for the independent existence or encouragement of chemical and physical oceanography. For those interested in the details of the development of oceanography in Canada I refer to an address by Dr. W.E. van Steenburgh[2] on the occasion of the opening of the Bedford Institute in October, 1962. Suffice it to say that the late 1950's and early 1960's saw

[1]Atlantic Oceanographic Laboratory, Bedford Institute, Dartmouth, N.S.

[2]Address at Special Convocation, Dalhousie University, Halifax, N.S., Oct. 24, 1962 by Dr. W.E. van Steenburgh, Deputy Minister, Department of Mines and Technical Surveys.

the strengthening of physical oceanography in this country - principally within the Bedford Institute under the auspices of the Department of Mines and Technical Surveys and largely as a result of van Steenburgh's personal motivation. Concurrently the N.R.C. contributed to the development of the subject through grants to marine science groups or departments in the east. The five-year program envisaged for the Institute in 1962 included such prophetic chemical objectives as the delineation of chemical properties of water and pollution research. By far the greatest proportion of effort was to be devoted to physical, geological and geophysical problems. Chemically speaking the sum total of the effort during the period 1962-67 was pitifully meagre and consisted essentially of the provision of salinity services coupled with some fundamental studies of silicate variability in the oceans and thermodynamic properties of sea water. In terms of actual effort this involved perhaps three scientists and about the same amount of technical assistance.

One of the brightest lights of this early period was undoubtedly the development of chemical oceanographic methods as described by Strickland and Parsons.[3] The Fisheries Research Board was active chemically speaking on the west coast through the inspiration and initiative of Strickland but as mentioned earlier their studies were almost entirely related to problems of marine productivity. The late sixties saw a moderate expansion of interest in marine chemistry with an increase in personnel at the Bedford Institute and the development of a research program in analytical chemistry largely devoted to the applications of neutron activation analysis.

I spoke of the support being given to universities for oceanographic studies. The universities principally concerned are U.B.C., McGill and Dalhousie. All three have staff and research students pursuing chemical oceanographic studies at the present time but just a matter of five years ago university interest was practically non-existent. For a number of reasons only a handful of Canadian students have graduated in chemical oceanography - one of the most important being that future opportunities for them were apparently extremely limited.

2. The Present

I have attempted during the previous discussion to outline the chronological development of marine chemistry up to about 1970. The total number of people engaged in the field in the Federal Government at 1970 amounted to at most about 12 scientists with a similar number of technical support personnel.

With increased concern for the marine environment coming to the surface a further change in attitude occurred. Impetus was given to this change with the creation of the Department of the Environment in 1971. Thus, in 1970 the Fisheries Research Board created environmental quality groups on both the east and west coasts with the general direction of their work focussing on the presence, distribution and transfer of pollutants in the various constituents of the marine food chain. A staff of approximately 16 are associated with this development on the east coast, located in the Marine Ecology Laboratory at the Bedford Institute, and currently an equivalent group is located on the west coast with objectives related to toxicology and pulp and paper wastes.

[3] "A Practical Handbook of Seawater Analyses", by J.D.A. Strickland and T.R. Parsons, Bulletin 167, Fisheries Research Board of Canada, 1968.

During the past two years the Marine Sciences Branch has also increased its effort in chemical studies of the marine environment with the creation of the Chemical Oceanography Division in the Atlantic Oceanographic Laboratory of the Bedford Institute. Here the staff now totals eight scientists and eight technical assistants (compared with a total of twelve prior to 1970). This group is almost totally concerned with broad chemical research studies including basic pollution research. It sees its future in a continuation of such studies with geographical emphasis being in areas such as the Gulf of St. Lawrence, Bay of Fundy, Hudson Bay and the Arctic. On the west coast a new group (four in total at present) is engaged in deep sea chemical oceanographic research.

3. The Future

The most important section of this discussion is undoubtedly the future efforts in marine chemical studies and more specifically in relation to coastal areas subject to human usage. This usage takes on many forms including recreational development, construction of oil refineries and deep water ports, harbour and marina development and hydroelectric schemes. There is no doubt that our work must relate to these current developments. It is equally true that we must accept the further exploitation and management of these zones but must be in the position to be able to reply intelligently to the questions of ecological vulnerability which will be unquestionably raised in the future. Some of these questions are now being asked but in my view we are ill-equipped and unsatisfactorily organized to provide the answers or undertake the rather basic but necessary work which is obviously required. It should also be pointed out at this time that the environmental studies and questions should be tackled prior to, rather than following, the industrial or recreational development. We must not try to close the stable door after the horse has bolted.

In considering these aforementioned requirements for effective management of our coastal areas I believe there are a number of things which we must do. These may be described as follows:

(i) Our understanding of the chemical changes occasioned by man and nature in the coastal areas must be developed.

To attain this objective there is a very clear and immediate need to establish a group whose prime responsibility will be to undertake surveys of the chemical quality of these areas. Anyone who has witnessed the disastrous pollution effects occasioned by ill-considered development must give thought to this matter. Geographically there are obvious present and pressing responsibilities on the east coast at Come-by-Chance, Lorneville and James Bay whilst on the west coast the Straits of Georgia are an excellent example of an area where such work needs to be performed. Beyond these immediate problems this group should look to the future development of areas with obvious potential for deep water ports, industrial development and recreational usage.

The work which must be performed by this "quality" group (the adjective is used unreservedly) would include chemical investigations of the basic properties such as salinity, temperature, oxygen content, suspended and dissolved load, general composition of major anions, cations and nutrients. In addition, trace constituents and pollutants, particularly those of specific concern to the area and those which may

be transported in and out of the region by various mixing processes both in the ocean and atmosphere, must be monitored. Attention must also be given to investigations of the biomass and sediments of the coastal area.

To some this suggestion may sound very much like a monitoring function similar to another water quality network. I would point out, however, that the coastal areas are no more static than the oceans, chemically, biologically and physically - in fact they are by far the most dynamic areas of marine interaction. They are the regions where major chemical changes occur as fresh water meets salt water, where tidal action influences the region of chemical interaction as well as the physical deposition of sediments. They also represent regions where meteorological influences play an important part in the transfer of air-borne substances to the marine environment and finally where marine biological life takes on many different forms from the fresh water regime. Chemically speaking the medium of the coastal zone presents its own unique problems in analysis. Those who remain unconvinced on this latter respect might benefit considerably from reading the results of the GEOSECS intercalibration study[4] on the measurement of trace constituents in sea water. The second responsibility which we must be careful to recognize is that:

(ii) Our knowledge and understanding of chemical behaviour in the open oceans must be improved and expanded.

This feature of our work is essential in that the coastal areas are not divorced or separated by any barrier, real or imaginary, from the open oceans. We know this very well since we have seen evidence on our beaches of shipwrecks that have occurred far out at sea, we have seen examples of foreign bric-a-brac that have been washed ashore and we know of countries where pollution is being carried to the shores by the ocean current system. It is apparent, therefore, that Canada must be cognizant of both the physical and chemical features of the world's oceans, but particularly the Atlantic, Pacific and Arctic Oceans. We must, therefore, understand these external influences on our coastal zones. It is only by conducting such fundamental studies that we will be able to understand or be in a position to comment or criticize the possible actions of other nations who may wish to dump or pollute intentionally these open ocean areas away from our shores. On a more positive note the future exploitation of the open oceans in mining, oil exploration or fishing requires much fundamental physical, chemical, geochemical and biochemical knowledge.

Finally in marine chemistry it must be recognized that:

(iii) Research on fundamental chemical processes to aid our understanding in both the coastal and deep ocean areas must be pursued.

In this connection it has become apparent from happenings over the past year that our understanding of the pollution problems in the oceans is sadly lacking, e.g. the mercury problem. It is quite a different matter from the fresh water situation where the culprit is often clear to see. In the oceans it was our initial belief that high mercury concentrations found in swordfish and tuna were a direct result of the industrial actions of man. Later studies indicate a growing number of sources of mercury addition to the oceans and considerably more complicated processes whereby our food products become contaminated.

[4] "Trace Element Intercalibration Study", by P.G. Brewer and D.W. Spencer, Publication 70-62, Woods Hole Oceanographic Institution, December, 1970.

Subjects where we must develop our understanding can be generally termed as chemical and/or geochemical transportation mechanisms. In consideration of the hazardous nature of the enormous variety of chemical substances which are presently accepted as essential to modern living we must know how these materials are transported within our environment. For example, is DDT transported via the atmosphere to the oceans by particulate matter, what is its residence time in the atmosphere, does it collect in surface films on the oceans, what are its subsequent transportation patterns in sea water, particulates in the oceans and in sediments, what are the biological pathways in the food web? These questions are still unresolved for many natural substances not to mention the additions of man-made chemicals to our environment.

In pointing out some of these aspects of the research problems in chemical oceanographic studies it is my aim to illustrate the breadth of the problems and, as a consequence, the type of people who are most suited to carry out the necessary studies. Scientists highly trained in narrow aspects of chemistry, e.g. organic synthesis or N.M.R. research, will experience considerable difficulty in orientation when they enter the chemical oceanography field. Although the techniques and equipment used are the same the medium of salt water presents many unique technical difficulties because of the complexity of its composition. Further, the interpretation of data demands an appreciation of the environment in which the chemical oceanographer is working. Thus, he must acquire and master knowledge on the physical behaviour of the oceans and the atmosphere plus the biological nature of the system to be successful in his work.

CONCLUSIONS

In concluding this discussion I would like to dwell for a moment on priorities and how to accomplish these objectives.

I believe our first priority is to develop immediately our knowledge of the current chemical conditions in our critical coastal zones. It is imperative, therefore, that the first move is to establish a group which would have a clear mandate for undertaking competent studies of the chemical quality of the coastal areas. As far as which organization should assume this responsibility this is an administrative detail. There is, however, one over-riding consideration. I am emphatic that the group be associated with current marine science groups for scientific reasons which have already been stated. It must be remembered that the group will not be just a chemical analytical monitoring group - its activities will need to be co-ordinated with those of the physical oceanographic personnel whose knowledge is essential to a meaningful program. Furthermore, the association with marine biologists is as essential as its liaison with the physical oceanographers.

I wish to comment further on the relationship of such a group to those present organizations devoting their efforts to more fundamental aspects of research into chemical changes in the marine environment. Within the freshwater environment we have seen already the need for continued <u>quality monitoring of water composition and variability</u>. Furthermore, we have seen the need for a second but parallel organization devoting its attention to current research needs and possible future demands. These two operations are essential and complementary. The more routine aspects of the work could well be carried out in isolation but the paramount consideration of critique will be missing from such a framework. Critical examination and re-examination is provided through the research activities which are, I repeat, essential to our activities.

Within the Federal Government structure at present we have research groups which are devoting their efforts to the understanding of chemical changes in the marine environment. Thus, I would not see much need to change this picture other than to encourage competent university personnel to participate in this research. I would hope that from this encouragement of universities would come the qualified Canadian scientists required to maintain these efforts for as long as they are considered necessary.

Eyebrows may be raised as to whether the proposed "quality" group would be encroaching on areas of responsibility within the Environmental Protection Service as they are envisaged at this time. This matter should be discussed but specifically I think within the context of legal responsibility which E.P.S. undoubtedly has within its terms of reference. Certainly the need for so-called "baseline studies" is apparent to all and is not being adequately met at this time.

Finally I would submit this proposal as a matter of some urgency as more and more we are confronted with fait accompli situations which would not be so were we able to take these initiatives as members of the Department of the Environment and draw alongside, if not ahead by a nose, of those who are concerned with resource exploitation.

SOME SOCIO-ECONOMIC ASPECTS OF COASTAL POLLUTION

K.B. Yuen[1]

We are here to talk about the coastal zone. I think it is safe enough to say that today there exist a number of coastal zone problems. For very obvious reasons, man has always favoured coastal areas for many of his activities, for example, marine transportation, industrial development, urban development, fisheries, recreation, tourism, to name a few. Quite often these are carried out in a relatively uncontrolled fashion which has led to many use conflicts. At the same time, man has also treated the sea as a perpetual sink for his wastes, but we now know that the assimilative capacity of the ocean is not unlimited. If we are to safeguard our environment and the health of the ocean, and if we are to make effective use of the coastal zone and its resources, we are going to have to take a systems approach, to manage and to control our activities there.

For many of our fresh water resources, we seem already to have been able to apply some management techniques, and while we haven't solved all of our fresh water problems at least there are some management tools available; these call upon not just scientific and technological understanding, but involve social, economic and operational issues as well. For the coastal zone and especially for the ocean, we seem to be a long way from effective management. This lag though may be quite natural; the oceans are vast and we're still a long way from understanding its many processes. The global situation is also complicated by political and legal differences and thus the development of a comprehensive management plan may still be many years in the making.

A number of us in this room are involved with various aspects of Canadian planning for the Stockholm Conference on the Human Environment. The format of that conference includes amongst other things the following five subject areas.

1. Planning and Management of Human Settlements for Environmental Quality.

2. Environmental Aspects of Natural Resources Management.

3. Identification and Control of Pollutants and Nuisances of Broad International Significance.

4. Educational, Informational, Social and Cultural Aspects of Environmental Issues.

5. Development and Environment.

[1]Marine Sciences Branch, Department of the Environment, Ottawa

These subject areas imply many socio-economic issues. To date, no international organization has yet to carry out any in-depth studies of the socio-economic aspects of marine pollution, but at least people are now recognizing that these issues are important. In this regard, it is encouraging to note that a pilot study on this subject is about to be carried out by the Organization for Economic Co-operation and Development (OECD) and because I think it's an important step towards solving some of the problems of coastal pollution, I would like to describe the study very briefly.

The pilot study will consider environmental degradation and pollution in the northern half of the Mediterranean Sea. The Mediterranean is almost enclosed and certainly there is a pollution problem of the whole sea. However, the countries on the southern half of the Mediterranean are much less industrialized than those countries along the north shore, and this study really represents a concern and a commitment by the six northern countries to cooperate in studying and solving their own pollution problem. In addition, much more oceanographic and pollution data is available for the northern areas. The economies of these countries depends, to a very large extent, upon the tourist industry, which explains their concern about marine pollution. In addition, these countries are relatively small compared to Canada, for example, and the conservation of natural resources on the land is also a major concern. The many problems of marine pollution, land-use conflicts and over-exploitation of the coastal zone make the area suitable for a pilot study and the OECD hopes that the results of this study will be applied to other coastal areas as well.

There are three main international and economic aspects of the problem as the OECD sees it.

1. The pollution of the common resource, the Mediterranean, is analogous to trans-frontier pollution. To resolve this problem, the Europeans feel, will require international agreement on (i) methods of measuring pollution, (ii) the location and amount of specific development which are sources of pollution, (iii) development of emission standards for the abatement of pollution and waste products.

2. One must consider the interaction of environmental degradation and international trade, primarily tourism.

3. There is the inter-relationship of environmental quality, the control of development and international investment. Uncontrolled exploitation of the environment might cause the redistribution of tourism investment to unpolluted areas. On the other hand, tight control of development might cause a transfer of industrial and other investment to other areas with less stringent regulations. Therefore, international agreement on realistic standards and controls might be needed to prevent this shift of investment to pollution havens.

The pilot study itself will be carried out by the OECD Environment Secretariat, either by the Secretariat staff or quite possibly by contract. The role of the six Mediterranean countries will be to submit the appropriate data and other advice and information as required by the study group.

The objective of the pilot study is to determine the national and international powers, institutions and instruments needed for effective control and treatment of coastal developments which could degrade the environment.

This will require knowledge on:

1. The location elasticities of coastal development.

2. The cost of treatment and of environmental quality and tourism.

3. The cost of treatment and of environmental control.

4. The demand on national investment resources and the effect of coastal environmental improvement policy upon economic growth.

Five criteria have been proposed to govern the collection of information.

1. The project will initially identify and concentrate on those pollutants of greatest significance and the location of their sources.

2. The priority for developing recommendations for the control and treatment of pollution is firstly those sources which pollute the coastal waters of other countries, that is long reaching pollution, secondly, those which directly affect tourism, and thirdly those which degrade the ecology and the appearance of the coastal regions.

3. The project will try to generalize the information and make a global analysis.

4. The project is restricted to the development of the coastal region, and river pollution will be treated as a single source.

5. The project will initially seek to determine the controls required and the related costs (a) to insure that despite developments, pollution in general does not increase by 1980 and (b) to prevent further irreversible ecological damage due to over exploitation of the coastal environment.

Very shortly the project will gather a meeting of experts to finalize the details of the study but at this stage the general plan involves two stages. Stage 1 lasting about one year will involve an assembly of facts about existing (1) population, (2) tourism, (3) industrial development, (4) other employment, (5) land under agricultural forestry use, etc., (6) area of coast subject to special environmental control, (7) laws, policies, plans, regulations, instruments and institutions concerned with the environmental impact of coastal development, (8) where available, any measures of existing pollution emissions, particularly the movement of air and water borne pollutants to other countries. Following this there will be an assembly of the following forecasts for 1975 and 1980. (1) demographic forecasts, (2) tourism forecasts, (3) industrial development, (4) urban growth, (5) the committed investment for urban development, for tourism development, and for treatment of household and industrial wastes, (6) loss of land from agricultural and other uses, (7) extension or introduction of conservation area natural reserves, etc.

Stage 2 of the study, also to last one year, will involve an estimate of the cost for ensuring that 1980 emissions do not in general exceed those existing at present. These costs estimates will be based on clearly defined technical assumptions and will be carried out for a range of variables. A range of estimates for specified alternative assumptions will also be calculated for different distributions and intensities of development. Estimates will be

made of feasible levels of investments and of control of development and land speculation in the regions studied. Following this, analyses will provide information to help identify the relationships between development of pollution, costs of maintaining environmental quality and effects on economic trade and growth and should provide the basis for recommendations for appropriate action for physical, economic, planning and investment policies. The study will also identify those policies and actions most dependent on international agreement for their success.

That in brief, is the OECD pilot study. At this point in time it is a very unique study, and hopefully it will provide guidelines and techniques for planning and managing our coastal zones. In the meantime, however, we are faced with many coastal zone problems which require action now; at the moment we seem to be taking a cross-mission task force approach to the coastal zone and while this is very useful, I think a better solution in the long run is to create a permanent management and planning body. In this regard, I would like to close off my talk by recalling several recommendations which came out of a Workshop on the Bay of Fundy held by the Marine Sciences Branch in September of last year. The workshop involved mainly scientists from within our Branch but also included staff from Inland Waters Branch. The main objectives of that workshop was to provide some rationale and some guidelines for Branch activities in the Bay of Fundy. Out of our discussions we further recognized the need for coastal zone management there as well as consideration of socio-economic issues. Two recommendations of the workshop are relevant here.

1. A separate group should be established, within the Water Management Service perhaps, to project coastal zone management, to co-ordinate departmental activities related to the coastal zone, to collate information and data analyses as required, to assess environmental consequences of new coastal development including an inventory of existing and future commercial development, to formulate departmental management policy for the coastal zone, to provide liaison with other departments.

2. The Marine Sciences Branch should develop within its organization a small unit with expertise in coastal zone management to insure direct communication with the marine scientists and technologists, to provide liaison between the Branch and the departmental coastal zone management policy group and to examine socio-economic issues in marine sciences affairs.

The need for coastal zone planning and management is rather clear. This Seminar is very timely because it gives us the opportunity to discuss and to recommend plans for action towards this end. I look forward to some concrete proposals coming out of the Workshops of this Seminar.

Fisheries and Wildlife

SIGNIFICANCE OF THE BEAUFORT SEA COAST FOR MIGRATORY BIRDS

Thomas W. Barry[1]

DESCRIPTION OF THE BEAUFORT SEA

The Arctic Ocean adjacent to the north coast of Alaska and Canada between Point Barrow on the west and Banks Island on the east is designated the Beaufort Sea. This region has an annual average temperature of about 10°F. The coldest month, February, averages -25°F, while July, the warmest month, averages 40°F. Precipitation amounts to only 3-6 inches annually. Snow usually falls every month of the year.

The Beaufort Sea is very shallow near the coast. The 10-fathom contour is generally 20 to 25 miles offshore. Tidal changes are only between one and two feet. But onshore winds can cause storm tides of up to eight to 10 feet during ice-free periods. A current generally moves from east to west along the coast throughout the year. In summer the waters carry heavy silt burdens caused by river effluents and wave action.

The polar ice pack may totally cover the Beaufort Sea at any season. Typically, however, an ice-free margin extending from three to 100 or more miles offshore exists at least intermittently between early July and late September. (Brooks _et al_., 1971; Ice Summary and Analysis, Meteorological Branch, 1962-70).

MIGRATORY BIRDS USING COASTAL ZONE

In the tropics, most bird species are non-migratory and terrestrial. In the Arctic the reverse is the case: most bird species are aquatic and migratory. The Arctic is represented by relatively few species but often by large numbers of individuals. Many of the Arctic species are economically important for native subsistence or for recreation, i.e. hunting and bird-watching.

The species nesting in Canada's western Arctic converge from wintering grounds representing one third of the globe; e.g. the Pacific and Antarctic Oceans and North and South America. Of the species nesting around the rim of the Beaufort Sea and the Arctic Islands, approximately two-thirds migrate through the Great Plains and the Mackenzie Valley and the northern Great Lakes, while the other third funnel through the Bering Straits and follow the coast of Alaska, Yukon and N.W.T. Water birds moving along the narrow leads that usually form between shore ice and Arctic pack ice in May and June can become extremely concentrated. Examples of species that use the

[1]Canadian Wildlife Service, Department of the Environment, Edmonton, Alberta

Arctic coast migration route can be illustrated thus: from the Antarctic, the Arctic terns, S. Pacific, Sabine's gulls, jaegers; from coastal Mexico and California, Pacific brant; from the north Pacific and Bering Sea, eiders, murres, and glaucous gulls. Some of the species using the interior migration routes also use the coast; for example, in the spring whistling swans move westward from the Mackenzie Delta along the Yukon and Alaska coast. Also many of the snow geese follow the coast of Tuktoyaktuk Peninsula enroute from the Mackenzie Delta to Banks Island. They also use the same routes in the fall.

The usual conception of bird migration is of a north-south direction, but for birds following the Arctic coast of North America a large part of the route has an east-west orientation. Some individuals of the Pacific brant migrate east-west nearly 2,000 miles along the coast, or about one-third of their total one-way migration; for example, from Chantry Inlet west to Bering Straits before turning south to the Pacific Ocean to winter in Mexico.

Some of the species using the coastal route of the Beaufort Sea are shown in Table 1.

FEATURES RESULTING IN CONCENTRATION OF BIRDS ALONG THE BEAUFORT SEA COAST

Along the Beaufort Sea Coast, there are some geographical and biological features that tend to concentrate birds when they are migrating, feeding, nesting or molting. For spring migrants, the existence of patches of open water or ice leads are most important for food sources and resting. Barry (1968) describes the high mortality among migrating sea birds in a season when the usual leads opening between the shore-fast ice and the Arctic pack does not occur. From Point Barrow to Dolphin and Union Strait and Prince Patrick Island 100,000 eider ducks died of starvation. (See also Ice Summary and Analysis, Canadian Arctic, 1964.) Open leads along the coast of North America is the rule each spring, rather than the exception; hence the chain of open water places formed by ice leads has developed over the millennia into a traditional migration route for migratory sea birds.

One of the more permanent open water areas is the polynia off Cape Parry, where an up-welling of rich sea waters provides food as well as year-round open water. That place is extremely attractive to sea birds as well as to sea mammals. The murre colony at Cape Parry is the only one for 1,000 miles east or west.

Strong coastal currents occur along the Arctic sea coast, especially at Baillie Islands, Tuktoyaktuk Peninsula and Mackenzie Bay. These currents are important not only for forming the sandspits, bars and lagoons that characterize the coast, but they also bring together Arctic and coastal (brackish) waters in the shallows. The result is an ideal feeding and molting place for Arctic sea birds, used by approximately 600,000 scaup, old squaws and scoters.

The barrier beaches, sand bars and lagoons, extending west from Tuktoyaktuk Peninsula and Mackenzie Delta to Herschel Island, and along the Alaskan coast to Point Barrow are important nesting grounds wherever they are broken into islands inaccessible to such predatory animals as the fox. Eiders, old squaws, gulls and terns are usually found nesting in such places. The sheltered lagoons behind the barrier beaches and sand bars serve as rearing and molting places for sea birds, as well as habitat for fish and other marine fauna.

TABLE 1. Bird Species Using the Arctic Coastal Migration Route

(*indicates species using interior route in part)

Species	Wintering Area	Summering Area	Estimated Population
Yellow-billed Loon	N. Pacific	Alaska, Arctic Islands	N.A.
Arctic Loon	N. Pacific	Low Arctic	N.A.
Red-throated Loon	N. Pacific	Low Arctic	N.A.
Whistling Swan*	U.S. mid-Atlantic	Arctic Coast	50,000
White-fronted Goose*	Texas, Mexico	Arctic Coast	85,000
Snow Goose*	Calif., Mexico	Coast, Banks Island	200,000
Pacific Brant	Calif., Mexico	Coast, Arctic Islands	50,000
Scaup*	U.S. mid-South	Some molt on coast	2,000,000
Old Squaw*	N. Pacific, Gt. Lakes	Coast, Arctic Islands	N.A.
Pacific Eider	N. Pacific	Arctic Islands)	1,000,000
King Eider	N. Pacific	Mainland, Islands)	
White-wing Scoter	N. Pacific, U.S. South	Mainland	N.A.
Surf Scoter	N. Pacific, U.S. South	Mainland	N.A.
Red-breasted Merganser	U.S.	Mainland	N.A.
Ruddy Turnstone	Pacific Islands	Arctic Islands	N.A.
White-rumped Sandpiper	?	Arctic Islands	N.A.
Baird's Sandpiper	S. America	Arctic Islands	N.A.
Sanderling	S. America	Arctic Islands	N.A.
Jaegers (3 species)	S. Pacific, Antarctic	Mainland, Arctic Islands	N.A.
Glaucous Gull	N. Pacific, Bering Sea	Mainland, Arctic Islands	N.A.
Thayer's Gull	N. Pacific	Eastern Arctic	N.A.
Sabine's Gull	S. Pacific	Mainland, Arctic Islands	N.A.
Arctic Tern	Antarctic	Mainland, Arctic Islands	N.A.
Thick-billed Murre	Bering Sea	Cape Parry	150

The deltas and tide flats of the Mackenzie, Kugaluk, Anderson and Big Rivers are major nesting grounds for ducks, geese and swans. They are enriched with each spring breakup, when high water and ice jams combine to spread water, mud and debris over all but the highest parts. The constant enrichment produces the best habitat for waterfowl. In the deltas submerged aquatic vegetation is abundant, and associated with it are swarms of minute animal life, ideal food for ducklings, goslings and cygnets. Food must be abundant to produce full-fledged birds in the short Arctic summer. Break-up occurs in early June and by mid-September the lakes and ponds have shell ice covering.

The Mackenzie Delta has a breeding population that varies from 80,000 to 335,000 ducks, depending on whether the prairies are dry and ducks are displaced northward. Approximately 8,000 geese and 4,000 swans nest in the outer delta of the Mackenzie. (Smith et al., 1964)

Several geographical features along the Beaufort Sea coast concentrate migrating sea birds into "passes" where natives have traditionally hunted them. Usually these places are between islands and the mainland, as at Herschel Island, Baillie Islands and Holman Island, or at the ends of points, as at Point Barrow or Warren Point. For example, at Holman Island in May and June, 1968, 22 hunters took 1,380 eider ducks. Anderson (1913) reports an almost continual migration of eiders past Baillie Islands. The male birds migrate westward as early as June 30, heading for molting grounds in the Chukchi Sea. In 1970 I saw female eiders with young migrating south through Prince of Wales Strait off Johnson Point on Banks Island as late as October 14. Thus, eiders are available at selected places on the Beaufort Sea coast for five months of the year.

ENVIRONMENTAL PROBLEMS OF SEA BIRDS IN THE COASTAL ZONE OF THE BEAUFORT SEA

The cruise of the Humble Oil tanker Manhattan and investigations of tanker port sites at Babbage Bight near Herschel Island, near Horton River on Franklin Bay, and on Darnley Bay, indicate that tanker transportation of oil from the Arctic might be feasible. Blumer (1970) presents data on the number of spills to be expected in handling and shipping oil. Glaeser and Vance (1971) report on U.S. Coast Guard experimental oil spills in the Beaufort Sea off Prudhoe Bay. Oil spilled in open water leads is, of course, contained by the ice. But the same leads are attractive to and concentrate on sea birds, so that even small oil spills in them would be extremely hazardous to large numbers.

In Oilweek magazine of March 13, 1972 the headline of the industry news story reads: "Imperial Oil is optimistic it will find in excess of 2 billion barrels of oil and 15 trillion cubic feet of gas in Canadian Arctic's Beaufort Basin.". The story points out that this amount of hydrocarbons is considered minimal for economic construction of pipelines, independent of Prudhoe Bay oil and gas south to markets. Imperial's optimism is apparently real, because plans are well underway for construction in 1972 of two artificial islands at the northern edge of the Mackenzie Delta to serve as ice resistant drilling platforms. It is still a moot question whether adequate measures for control of possible well blow-outs and marine pollution have been prepared.

In the area between the Mackenzie Delta and Prudhoe Bay, Alaska, gravel deposits are said to be worth more than gold mines. Gravel will be required for pipeline construction, roads, drilling pads and to top off the artificial islands. Gravel is available in this region only in stream beds, eskers on Richards Island, and from barrier beaches and sandspits. Except for the eskers, the sources of gravel are also vitally important in the life history of sea birds as well as of the fish and invertebrates in the food chain.

For some unexplained reason, many species of birds and mammals are terrified by helicopters, even more than they are by fixed-wing aircraft. Already exploration activities have demonstrated the effects of helicopters on nesting geese (Barry and Spencer, 1972). We are assured that helicopter activity will increase along the coastal zone of the Beaufort Sea as drilling and seismic work continues.

Native utilization of the migratory birds of the coastal zone is sketchy. But, although the culture is changing from subsistence living, hunting for food continues. Meanwhile hunting methods and equipment have increased in efficiency. We estimate that 8,000 snow geese, 750 white-fronted geese, 2,000 eiders and 9,000 ducks are taken annually in the coastal region of the Beaufort Sea in Canada.

DISCUSSION

The sea birds of the Beaufort Sea coastal zone are represented by possibly several million individuals. Considering their abundance, we know disturbingly little about them, and even less about their relationship to other marine fauna in the region.

To date the development of the Arctic, (an area of many poorly understood problems connected with permafrost, aboriginal culture and ecosystems, etc.) has proceeded on a cost accounting system traditional in industry and government brought from the temperate regions. Thus, it is more expedient and less costly say, to scoop up a barrier beach for a drill island than it is to wait until freeze-up to truck gravel over ice for 40 to 70 miles from a less critical site. Until we have more data, it is difficult to assess the economic and ecological implications of development on sea birds and other fauna.

CONCLUSION

By treaty, migratory birds are designated an international resource. Little is known of sea birds numbers, biology, food chains, migrations and contribution to the environment. We can avoid a lot of headaches by not having good background information, in the spirit of "what we don't know won't hurt us". At the moment, our basic knowledge lags behind advances in northern exploration and exploitation, so that we cannot predict the changes our activities may make in the Arctic marine environment. Nor can we recommend measures to minimize changes or damage. The responsibility lies with us to correct our ignorance.

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ENVIRONMENTAL QUALITY RESEARCH AND

AQUATIC ORGANISMS IN THE COASTAL ZONE

Donald C. Gordon, Jr.[1]

INTRODUCTION

The purpose of this paper is to briefly review potential pollution problems in the coastal zone environment, and then to outline the direction that ecological research should follow in order to solve them. Many of the ideas and suggestions discussed in this paper were obtained from an excellent and timely report entitled Marine Environmental Quality, which was recently published by the U.S. National Academy of Sciences. These of course have been modified somewhat and integrated with the opinions of myself and colleagues in the MEL Environmental Quality Program. Hopefully, the result is a well-balanced guide of how environmental quality research on aquatic organisms in the Canadian coastal zone should proceed.

Man's impact on the coastal zone environment is considerable and widespread, and is increasing each year. As a result of human activities, particularly in the industrialized parts of the world, materials are entering the oceans at rates which are comparable to those at which substances are introduced by natural weathering processes. Many of these man-derived materials, especially those transported by rivers, enter the ocean in the coastal zone. It is therefore logical to assume that any resultant effects from these pollutants would probably be most pronounced in the coastal zone because of the greater fluxes and concentrations. This assumption is correct to a certain degree, and this paper is devoted to how these effects should be studied. However, we must not be caught in the trap of thinking that all possible deleterious events will occur in the coastal zone and ignore what might be happening further offshore. Recent studies have shown that several major, recognized pollutants are transported principally via the atmosphere, and hence can be injected into the sea hundreds of miles away from land.

POLLUTANTS OF CONCERN

First, we must identify those materials which are actual or potential pollutants in the coastal zone. These can be divided into two distinct classes: natural and artificial. The natural pollutants are those compounds which are products of natural processes and which have long been involved in biogeochemical cycles before man evolved. However, because of man's activities, the fluxes of these compounds into the environment have accelerated, in some cases dramatically, which has resulted in increased concentrations near the points of injection. Such natural pollutants include unrefined petroleum components, heavy metals such as mercury and cadmium, nutrients, micro-organisms, and the major bulk of pulp mill effluents. Studies of these

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natural pollutants are complicated by the need to distinguish between the natural background concentrations, which can fluctuate, and the amounts added as a result of man's activity. Failure to recognize and appreciate natural concentrations can lead to faulty interpretations and perhaps over-reaction to a particular situation.

The artificial pollutants are those that do not occur naturally, but that have been synthesized by man. They include certain refined petroleum products, halogenated organic chemicals such as DDT and PCBs, metallo-organics, organic phosphates, detergents, certain enzymes and chelators, and pharmaceuticals. Their presence in the coastal zone indicates contamination by man. This broad group of pollutants is generally more dangerous than natural pollutants, because, being geologically new, natural systems have had little chance to evolve suitable mechanisms capable of utilizing, degrading and recycling them.

SCIENTIFIC APPROACH

Having now briefly reviewed the pollutants we can expect to encounter in the coastal zone, how should we begin to study the problems that they pose. Most environmental quality research in the coastal zone to date has been very superficial, generally consisting of acute toxicity testing. There is considerable doubt about the usefulness of this kind of data by itself. It has become obvious that environmental quality programs must be attacked in a much broader framework of carefully planned field and laboratory investigations.

There are two broad and closely related approaches that can be taken in environmental quality research. They are how do organisms affect pollutants and how do pollutants affect organisms. The first approach considers the transfer and alterations of a pollutant as it passes through biological systems, while the second considers the effects a pollutant can cause on organisms which come into contact with it. Practically all research to date has taken the second approach which has given us data which are almost impossible to interpret in terms of natural conditions. More effort must be placed on studying the transfer processes occurring in nature. With this more fundamental information, we will be able to design more efficient experiments to test effects and to interpret the results more effectively. A well-rounded research program should try to follow both of the above approaches simultaneously.

EFFECTS OF ORGANISMS ON POLLUTANTS

Knowledge of the ultimate sources and means of dispersal and transport of a pollutant is very important to ecological studies, but since interest in this aspect is shared with geochemists, physical oceanographers, atmospheric chemists, and air-sea interaction scientists, I won't spend any time discussing them. We shall assume that the pollutants of interest have already reached the coastal zone.

The first aspect to consider is the availability of a pollutant. What physical and chemical form(s) is it in when it is taken up by marine organisms. Potential sources include:

- Dissolved in water as free or complexed ions

- Associated with dissolved organic matter

- Adsorbed to or incorporated in either inorganic or non-living organic particulate matter

- Adsorbed to the surface of organisms

- Adsorbed to or incorporated in sediments

The next aspect to understand is by what mechanism of uptake does a pollutant enter an organism from the environment. A wide variety of mechanisms is possible:

- Active transport across a membrane. This is an energy-requiring process that works against a concentration gradient.

- Physical/chemical processes, including diffusion, absorption and precipitation

- Pinocytosis, the ingestion of micro-particles by micro-organisms

- Ingestion of suspended particulate matter by filter-feeding organisms

- Ingestion of sediment by deposit-feeding organisms

- Ingestion of contaminated tissue by raptorial feeding organisms

Once in the food web, pollutants can be transferred from organism to organism by feeding. The food web has been postulated to be a continuous extractor which tends to concentrate certain pollutants in the oldest organisms of the highest trophic levels. This hypothesis should be tested and compared with other mechanisms of concentration. It is important to understand the biochemical associations of a particular pollutant. Is it travelling in the lipid pool as do the halogenated hydrocarbons or does it associate with protein as mercury appears to do?

It should be understood that as well as moving a pollutant up the food web, biological transfer may also alter the form of the original pollutant by decomposition, detoxification mechanisms, dissolution, and biochemical modifications. These potential transformations should ideally be examined at each trophic level.

Studies of pollutant transfer in the coastal zone, and in any other geographic region, should culminate in the development of sound predictive models based on both field and laboratory studies. These models should incorporate information on transfer pathways, flow rates, residence times and concentrations in different reservoirs, and overall budgets. Compartment models appear to be particularly useful in this application. Properly constructed, mathematical models can supply both a valuable insight to the dynamics of pollutant transfer and a useful predictive capacity.

The most serious problem in trying to construct models capable of describing upset biological systems is that we do not understand the dynamics of undisturbed ecological systems very well. Hence there is little in the way of either fact or theory to begin with. For this reason, it is imperative that we continue and expand studies of undisturbed ecological systems within the coastal zone for comparison with disturbed systems.

EFFECTS OF POLLUTANTS ON ORGANISMS

Sound predictive models will help us focus on the important aspects that need understanding in the second approach mentioned above, that is what effects do pollutants cause as they move through biological systems. This general topic is the more applied or practical end of environmental quality research for it supplies the information needed to make sound management decisions which will insure the continual existence of a healthy coastal zone. Without this information, decisions that affect the coastal zone would undoubtedly be made on purely economic and political considerations which have little or no sympathy or understanding for natural processes. This information is required soon, for the need for effective environmental management in the coastal zone becomes more apparent each year.

As mentioned earlier, most work to date on the effects of pollutants on organisms has been done by acute toxicity experiments. In these, a limited range of test animals is subjected to pollutants for a given length of time and the dose required to kill 50% of them is used as the basis for a standard. There are many shortcomings to this practice, the principal ones being:

- The organisms tested are usually selected on the basis of how easily they can be kept in the laboratory. Hence the hardier species are used and they could be less susceptible to pollutants.

- Only adult organisms are generally used and not the more vulnerable eggs and larvae.

- Uncertainty as to whether a pollutant is added to the experiment in the exact form and concentration at which it is presented to test organisms in nature.

- Effects other than death are not taken into account.

Long-term, sublethal effects on behaviour, survival, feeding and reproduction, which can have just as much effect on a population or organisms as immediate death, have not been properly evaluated. Additional research is required to develop more meaningful and legally functional criteria that consider these more subtile effects. These criteria must be developed with both a knowledge of the ecological aspects involved, hence the need for precursory information on the transfer dynamics, and a realization of the ultimate use of criteria required to make and enforce anti-pollution laws.

The research effort on the effects of pollutants on organisms should proceed simultaneously at four different organizational levels: the cellular, whole organism, population and community. The classical acute toxicity test applies only to the whole organism level. As the level of organization increases, the time required to perform meaningful research increases as well. Studies at the cellular level can be carried out in a matter of weeks while studies at the community level will take years. The need for time-series observations also increases with organizational level.

Studies at the cellular level can provide a quick and relatively simple method of discovering toxic or inhibitory effects of a suspected pollutant. Parameters useful to study include respiration, enzyme effects, energy metabolism, membrane permeability and function, and photosynthetic radiocarbon uptake. Research at this level should also be addressed to understanding the actual mechanisms of toxicity.

Specific organisms selected for whole organism studies must be the most sensitive and ecologically important organisms. Experiments must be conducted over longer time periods and include both laboratory cultures and natural organisms. More information on the effects of pollutants at different life stages is required. Further studies on threshold levels should be undertaken with regard to sensory physiology, behavior, reproduction and development.

Studies at the population level are necessary to determine how entire populations of organisms are being affected by a pollutant. They should center on populations of organisms known to be target species, that is the species most adversely affected. Sampling programs must be carefully designed to provide statistically valuable data and to take into account the natural population fluctuations. Included in population studies should be:

- Biogeographic maps of species average distribution and spacial variation

- Population size estimates for all life stages including eggs and larvae

- Determination of age structure and sex ratio

- Population fecundity

- Determination of food source

- Productivity

Studies at the community level are necessary to keep track of the overall health of a large geographic area such as the coastal zone. Of the many species of plants and animals comprising a community, not all will be able to adapt to a change in environmental conditions, and the stability, diversity and species composition of the community will undoubtedly change. These changes can be a valuable early warning system if observed and properly interpreted. Studies of changes in community structure along gradients of known pollution, such as near sewage outfalls, can be very useful. Care must again be taken not to confuse changes in community structure due to pollutant effects with natural changes. Parallel studies on both polluted and virgin communities will be most rewarding.

CONCLUSIONS

The environment quality problems requiring attention in the coastal zone, and in other marine areas, are now recognized and well-defined. Our task now is to proceed with the necessary research, using all possible resources, in order to provide the information we need to assure the survival of an ecologically-healthy coastal zone.

BIOLOGICAL CONSIDERATIONS OF FISHERIES IN CANADIAN COASTAL ZONES

K.S. Ketchen[1]

INTRODUCTION

From the start it is important that we define the term "coastal zone", since it undoubtedly means different things to people with different scientific or technical backgrounds within our new Ministry. From the standpoint of fisheries, it is difficult to avoid a definition which encompasses less than the entire continental margin, namely, the region between the high-tide mark and the base of the continental slope. Further, when we consider that not only marine species but also anadromous species (the salmons) play a very important role in the fisheries of the coastal zone, we are tempted to include the drainage systems of all rivers emptying into the sea, and indeed, so they should be, for in their own right they make significant biological and physical-chemical contributions to the general ecology of the shelf and slope. In any case, this all-inclusive ecosystem is much too large and complex to do justice to its many biological aspects in a seminar of this kind, particularly since I am required to provide passably intelligent comments on coastal fisheries of both the Atlantic and Pacific. It is my intention therefore to restrict my remarks largely to marine fish and fisheries, and the waters to the base of the continental slope.

CHARACTERISTICS OF THE COASTAL ZONE

To the uninitiated observer, the fact that an overwhelming proportion of the world's marine fish catch is made in the coastal zone probably leads him to the conclusion that this concentration merely reflects man's reluctance or inability to venture far from land. But this is quite untrue. The shallow coastal zone is much more productive, being richer in nutrients (the basic ingredients for life in the sea) than are the wide expanses of open ocean.

Through photosynthesis, the process by which the energy of sunlight is trapped by the chlorophyll of minute plant life (phytoplankton) and used to build up complex organic substances, the base is laid for a complex food chain which leads ultimately to the support of the fishes harvested by man.

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The high nutrient content of the coastal zone can be attributed to a number of factors:

(1) the upwelling process draws nutrient-rich waters from the dark ocean depths into the shallower depths penetrated by sunlight (i.e. into the euphotic zone);

(2) tidal and wind-driven currents over the relatively shallow water of the shelf increase the transfer of nutrients from deep to shallow. At the same time the shallowness of the zone itself results in more rapid recycling of nutrients than is possible in the deep ocean;

(3) the strong discharge of fresh water into the sea from large rivers brings about the entrainment of deep water to the surface, in much the same manner as the upwelling process; and

(4) river systems, both large and small, pump still other kinds of nutrients and trace elements into the sea from the lands which they drain.

These processes of enrichment apply in varying degrees to the coastal zones of both the Atlantic and Pacific. However, there is an interesting contrast. In the northwestern Atlantic adjacent to Canada the coastal zone (as defined here) is very much larger than that off the Pacific shore. Added to this is the effect of the convergence of cold waters of the Labrador current and warmer waters of the Gulf Stream from the sub-tropical western Atlantic. This phenomenon not only produces turbulence which brings nutrients into the euphotic zone but also concentrates the nutrients, the phytoplankton and zooplankton which, in turn, attract large concentrations of harvestable fishes. The same phenomenon occurs in the northwestern Pacific off the cost of Japan, the site of another of the world's great fisheries -- but not off our west coast.

FISH LIFE IN THE SEA

Most of the fishes which inhabit the coastal zone are egg layers, but their parental instincts are much less responsible (if you will pardon my anthropomorphism) than those of, say, the salmons which take a lot more care of their eggs at spawning time. Some marine fish produce sticky or dense eggs which adhere to sand particles on the ocean floor or at least float near the bottom until the larvae hatch. Many produce buoyant, pelagic eggs which drift at various depths at the mercy of tidal or wind-driven currents, often for a considerable time before and after hatching. Initially, the larvae are fed by their own yolk supply but when this is exhausted they become dependent on the microscopic plant and animal life floating around them, which may or may not happen to be of the right kind and quantity. At the same time the larvae run the risk of being devoured by larger plankton or plankton-eating fishes. Eventually, depending on the species, the larvae collect in suitable nursery areas -- ocean currents permitting -- and begin a life which leads them to adulthood some years later.

A phenomenon common to most marine fishes is the yearly variation in success of spawning. Brood strengths may be many times larger in some

years than in others, and this may lead eventually to substantial variations in the abundance of adults or those sizes of fish which attract fisheries. Periods of low abundance are often severe enough to bring about dislocation of the industry and hardship to fishermen.

The reasons for the fluctuations are many, and fisheries science has not been particularly successful either in isolating the critical factor or factors, or in finding ways of predicting future events for the benefit of industry and those charged with the responsibility for management.

The role of the fisheries scientist is a difficult one, not only because of the vastness of the ocean environment, but also because of the indirectness of his observations. He works in the dark, as it were, depending on various sampling techniques which he hopes will supply an accurate indication of what really is going on, and thus provide him with the information needed by fishery managers. Compare, if you will, the relative ease with which the forester or agriculturist copes with essentially similar situations on land.

RESPONSIBILITIES FOR BIOLOGICAL RESEARCH

Responsibilities for biological research in the coastal zone, as well as in waters much farther from shore, are clearly defined in the Fisheries Research Board Act. The Board, or what apparently has replaced it as the Research and Development (R & D) Branch of the Fisheries Service, "...has charge of all federal fishery research stations in Canada and has the conduct and control of investigations of practical and economic problems connected with marine and freshwater fisheries, flora and fauna...." There are four stations or laboratories concerned with the Atlantic coastal zone and three on the Pacific.

On both coasts the Operations Branch of the Fisheries Service has the responsiblity for the conservation and rational management of the marine and anadromous species. This Branch is the principal client of the R & D Branch, relying in large measure upon the latter to provide the sound biological background needed to implement effective conservation measures within its area of jurisdiction. In waters beyond Canada's exclusive fisheries jurisdiction, the government presses for agreements (with varying degrees of success) with other nations through its involvement in several international treaties. To achieve acceptable agreements and to back up claims of special interest in the renewable natural resources of the coastal zone and beyond, Canada requires the strong support of fisheries science, and it is here also that the R & D Branch performs an important role. These are but a few of the responsibilities of the R & D Branch. There are others dealing with the enhancement of resources, commercial and recreational, development of new and improved products, and environmental research concerned principally with biological aspects of pollution and the impact of logging operations -- all subjects of considerable importance but which can be mentioned here only in passing.

There is a unique feature of the coastal environment and its resources which has considerable bearing on research policy. Except for a few special cases, the resources of that part of the coastal zone lying within Canadian fishery jurisdiction are the common property of Canadian fishermen. Outside the area of jurisdiction they are the common property of many nations, by reason of use: more than 16 nations in the Atlantic

and 4 in the Pacific*. The non-proprietary users have no commercial incentive to invest in the conservation of a common property resource, in the same way that a farmer would soon lose interest in sowing a crop if other farmers were free to knock down his fences and compete for the harvest. For this reason, and because of the fragmented nature of the fishing industry, there is no real alternative to government sponsorship of fisheries research.

On the broader, international scene, there are numerous examples of inter-governmental cooperative research, but examples of effective joint conservation measures are much less numerous. As frustrations build, there is indication that coastal states, Canada included, may take unilateral action to gain control of the exploitation and management of all renewable resources on the adjacent coastal shelf. World recognition of this authority is unlikely to be accepted unless we can demonstrate that our decisions are based on scientific evaluation.

STATE OF THE ART

A thumb-nail sketch of the historical development of fisheries research may help in understanding some of the activities and courses of action being taken today to solve current and future problems facing the Ministry.

Bilogical sciences, in general, had their early beginnings in the identification of species and description of their natural histories. This activity extended well into the present century, and while it is still going on and remains important in itself in the fisheries world, the naturalist has been succeeded by the quantitative biologist whose interests lie in the dynamics of fish populations, in communities of fishes and in their interactions. Recognition of the importance of information on the estimated size of populations, and the growth and mortality rates of individuals within these populations dawned rather slowly. Indeed, it was not until the middle 1930's and later that investigators began to develop elementary models to demonstrate the theoretical basis for management of fisheries. Knowing the parameters of growth and deaths due to fishing and to natural causes, it was possible to demonstrate, for example, the theoretical minimum size at which a species should be caught so as to achieve the maximum yield from a given number of recruits. In other words, it appeared to be theoretically possible to manipulate a population of fish for the maximum benefit of man by adjusting the minimum size at first capture (e.g., by setting size limits or minimum mesh sizes for nets) or by adjusting the mortality rate due to fishing (e.g., by setting limits to the amount of fishing effort or establishing quotas).

This approach reached its nadir in the late 1950's. Although simple in concept, the theory was difficult if not impossible to apply to international fisheries. In areas where overfishing was most obvious, nations were rèluctant to give up their sovereign rights and abide by the regulatory measures proposed by international bodies. Where the theory

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*Excluded from consideration here are the 5 species of Pacific salmon, and the single species of salmon in the Atlantic. These migrate many hundreds of miles beyond waters of Canadian fishery jurisdiction but are claimed as the private property of Canada.

was applied, the results in some cases were not as expected, thus serving as a non-too-gentle reminder that simple models, while convenient for computational purposes, were far too simple to reproduce faithfully events in nature. For one thing, much of the theory was developed for application to single species fisheries which, by and large, are the exception rather than the rule.

In fisheries where several species are caught simultaneously with the same kind of gear, we can expect to find markedly different requirements for the best utilization of each. In our domestic fisheries, the tendency is to concentrate fishing effort on the most desirable (highest priced) species. It may become overfished while the less desirable ones remain underfished, but any regulatory measure which might be required to conserve the most desirable one usually operates in such a way as to minimize the desired effect, and at the same time encourage inefficient exploitation of the species requiring no special measures.

The problem of conservation in areas where vessels of other nations are competing is aggravated by the fact that, because of differing economic bases upon which these other nations operate, what is the most desirable species to one is not so to another. By the same token, the definition of overfishing, being deeply rooted in economic benefits vs. costs of operation, differs among competing nations because of different living costs and standards.

The single species concept of resource management is giving way gradually to the concept of managing whole ecological units -- units consisting of a number of species, including those which constitute several links in the food chain, not just the highest priced fish near or at the end of the chain. This makes some sense since it comes closer to the utilization of the total edible or usable biomass produced in a particular area and period of time. In our high-cost economy (particularly the west coast) discarding or avoiding species which are of no commercial interest at the present time, could have serious long-term consequences since these undesirable species might well preempt the rich feeding grounds of those which are desirable. In areas beyond our jurisdiction the vacuum-cleaner policy of fishing by less affluent nations takes care of this dangerous possibility, because very little of what they catch is ever returned to the sea. Their interest is in volume production, with little regard being paid to the kinds and qualities of the species involved.

The tactics of foreign fishing operations, the manner in which they attack a particular fishing ground in great force, clean up the species available there, and then depart for some other fishing ground, serves to underline the necessity of developing management policy based on large ecological units rather than on individual species, or those of top economic value to Canada.

The study of food chains and the energy flows from one trophic level to another and the chance of predicting, if not manipulating, these flows to maximize the dollar value or weight of usable protein to be gained from an ecosystem, may offer new, more rational bases for management of fisheries resources. However, this systems approach, if it is to succeed at all, is going to require very much more biological and oceanographic research effort than is currently being expended.

I have mentioned the subject of prediction and it is with this particular topic that I should like to conclude my remarks on the require-

ments for effective fisheries management in the coastal zone. Management would indeed be a simple matter if we knew in advance of each year's fishery how much of the ecosystem's productivity can be removed and at the same time maintain the resource at a level which provides the maximum sustainable yield. Unfortunately, events in the sea are not easy to predict. I mentioned earlier some of the critical stages in the life history of fishes -- those which occur during the egg and larval stages when future productivity of a resource hangs in the balance subject to the whims of the physical environment.

Prediction of environmental events places heavy demands on oceanography -- a science still so young that little of the energy (funds and people) required to hasten its development can be spared for a service to fisheries management. Regrettably but understandably, most of the principles of oceanographic processes have stemmed from intensive studies on the relatively uncomplicated high seas, not in the extremely complex coastal zone which supports our major fisheries.

We are all aware of the difficulties and frustrations of weather prediction, despite the existence of broad networks of monitoring stations across our country. "Weather" in the sea, though slower to change than atmospheric weather, possesses much the same kinds of anomalies, flow patterns and fronts which directly or indirectly can play havoc with the reproductive success of fish populations. There is ample evidence today to suggest that there are cyclical patterns in the "climate" of the sea which have long-term subtle effects on the abundance and distribution of fish populations. Short-term changes in the "weather" of the sea and long-term changes in "climate" have their origin in regional and global atmospheric circulation. The link between meteorology, oceanography and fisheries is an obvious one. I should hope that the need for close cooperation in all three lines of endeavour, for better understanding of the requirements for renewable resource management, is equally obvious.

THE COASTAL ZONE

ITS BASIC ECOLOGICAL PROPERTIES AND SUBDIVISIONS

K. H. Mann[1]

We are here to discuss the Coastal Zone as one aspect of Environment. By environment we presumably mean the human environment, and there is a tendency to use the word as if this is its basic and original meaning. However, ecology was defined many years ago as the study of the interrelations of organisms and their environment. Water is the environment of fish, mud or sand is the environment of clams. In the Marine Ecology Laboratory we are much concerned with the interactions of organisms with their environment, and man may be regarded as one more species interacting with its environment.

THE NEED FOR A SYSTEMS APPROACH

One clear principle has emerged in ecology in recent years: we now know that you can get only so far by studying the interactions of a single species with its environment. After a time, this line of enquiry leads to unanswerable questions. It is then necessary to adopt a different point of view and consider all the organisms and their environment as an interacting system. So it is with problems of the human environment. It is possible to discuss this environment in terms of the physics and chemistry of the atmosphere, the geology of the shoreline, or the properties of the water as they affect man directly, but the problems that really bother us are the complex biological interactions. We need to know what are the effects of atmospheric pollutants on man's physiology, on the growth of his crops and animals, and on the weather to which they are exposed. We need to know how changes in sedimentation patterns affect the food chains of bottom-living fishes which man harvests. And the real problems with polluted waters are not the chemicals they contain, but the micro-organisms that generate obnoxious smells, and the fish stocks that disappear from their vicinity. So the theme of this presentation is this: *to understand the coastal zone and manage it wisely we must understand its characteristic biological systems.*

A comprehensive classification of the coastal ecological systems of the United States has been made by Odum, Copeland and McMahon (in press), but it would be out of place to attempt a review of such a broad field. Instead, I should like to draw attention to some biological systems that have been studied at the Marine Ecology Laboratory and highlight some of the findings which have management implications.

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[1] Fisheries Research Board of Canada, Marine Ecology Laboratory, Bedford Institute, Dartmouth, Nova Scotia.

To illustrate some of the interactions of a complex biological system I should like to refer to Nova Scotia's most valuable seafood - the lobster. The system of which it is part has as its core the food chain: seaweeds → sea urchins → lobsters. Sea urchins have long been recognized as being detrimental to seaweed beds. Not only do they eat seaweeds, but they often just bite them off at the base and leave them to float away. There are many places around our coasts where suitable conditions for seaweed growth occur - from high water down to about 70 feet - but where the underwater scenery is like a desert ravaged by sea urchins.

The urchins can be killed with quicklime and the seaweed returns, but the question remains, why do these outbreaks of the pest species occur? In California, where they denude beds of the commercially important *Macrocystis* weed, they concluded that sea otters were the natural predators of sea urchins. As human settlement increased the sea otters became scarce and the urchins increased. Normally, one would expect the sea urchins to halt their population growth when they ran out of seaweed in an area - they are not very mobile - but it turns out that where there are sewage solids and dissolved material they can survive on that, and stay around to eat off any young seaweed plants that have the temerity to grow.

In Nova Scotia, sea urchins are eaten by shore fishes - flounder, sculpin, wolffish; by crabs and lobsters. The only species that is reduced in numbers by human interference is the lobster, and in several areas which we have studied the dense sea urchin patches coincide with areas of intense lobster fishing. So, if we are right, a simplified version of this system would be: man eats lobsters, lobsters fail to keep down the sea urchin populations, sea urchins produce underwater deserts by overgrazing seaweeds, and the whole basis of production, the primary producers, are removed.

Other factors in the system include the following: the seaweeds need strong wave action and clear water for healthy growth. Building wharves and dredging mud may interfere with these factors. Harvesting Irish Moss has been shown to kill many young lobsters. Sea urchin populations may be kept going by sewage effluents - this seems to be true in Bedford Basin - and any calculation of the critical level of the lobster population below which it is dangerous to go must take into account the relative numbers of other predators, fish and crabs. One aspect of the system - a description of the pattern of energy flow, is given in Fig. 1. It shows that the seaweed production is far in excess of the food requirements of the herbivores - most of it is carried out to sea as dissolved and particulate organic matter - and that the production of organisms which are potential food of lobsters is far in excess of the food requirements of a 'typical' lobster population. There are germs of an idea for aquaculture here, if the competitors for food of the lobsters could be kept out or eliminated.

COASTAL INLETS AS BIOLOGICAL SYSTEMS

St. Margaret's Bay

The system used as an example in the preceding section was studied in St. Margaret's Bay (Fig. 2). This bay was chosen by the Marine Ecology Laboratory for baseline studies of an inlet having virtually unpolluted water and abundant stocks of fish and lobsters of commercial importance. The approach has been multi-disciplinary: biological, physical and chemical work

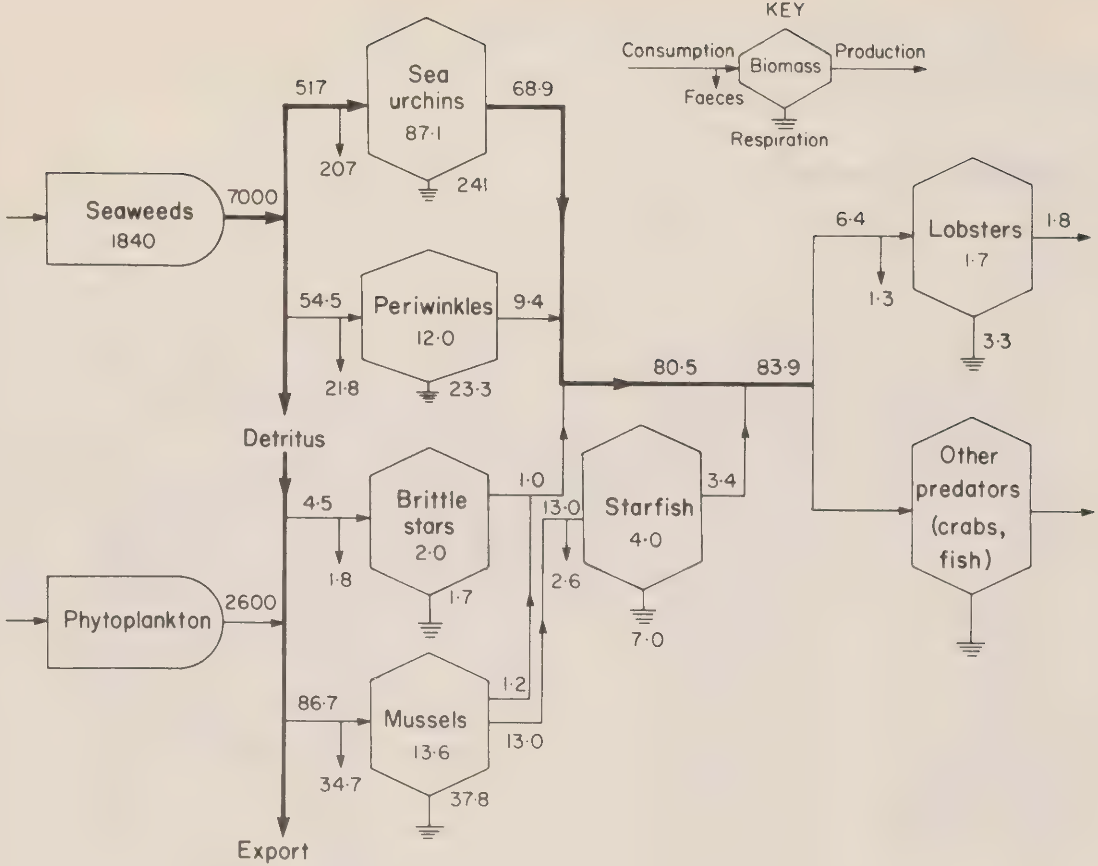

Figure 1. Diagram illustrating energy flow in a seaweed-lobster community. Primary producers, using sun's energy, on the left. Four categories of herbivores in the next column. Starfish are predators on mussels, and the productivity of all these animals is shared between lobsters and other predators. From Miller, Mann & Scarratt (1971) (J. Fish. Res. Bd. Canada 28: 1733-1738).

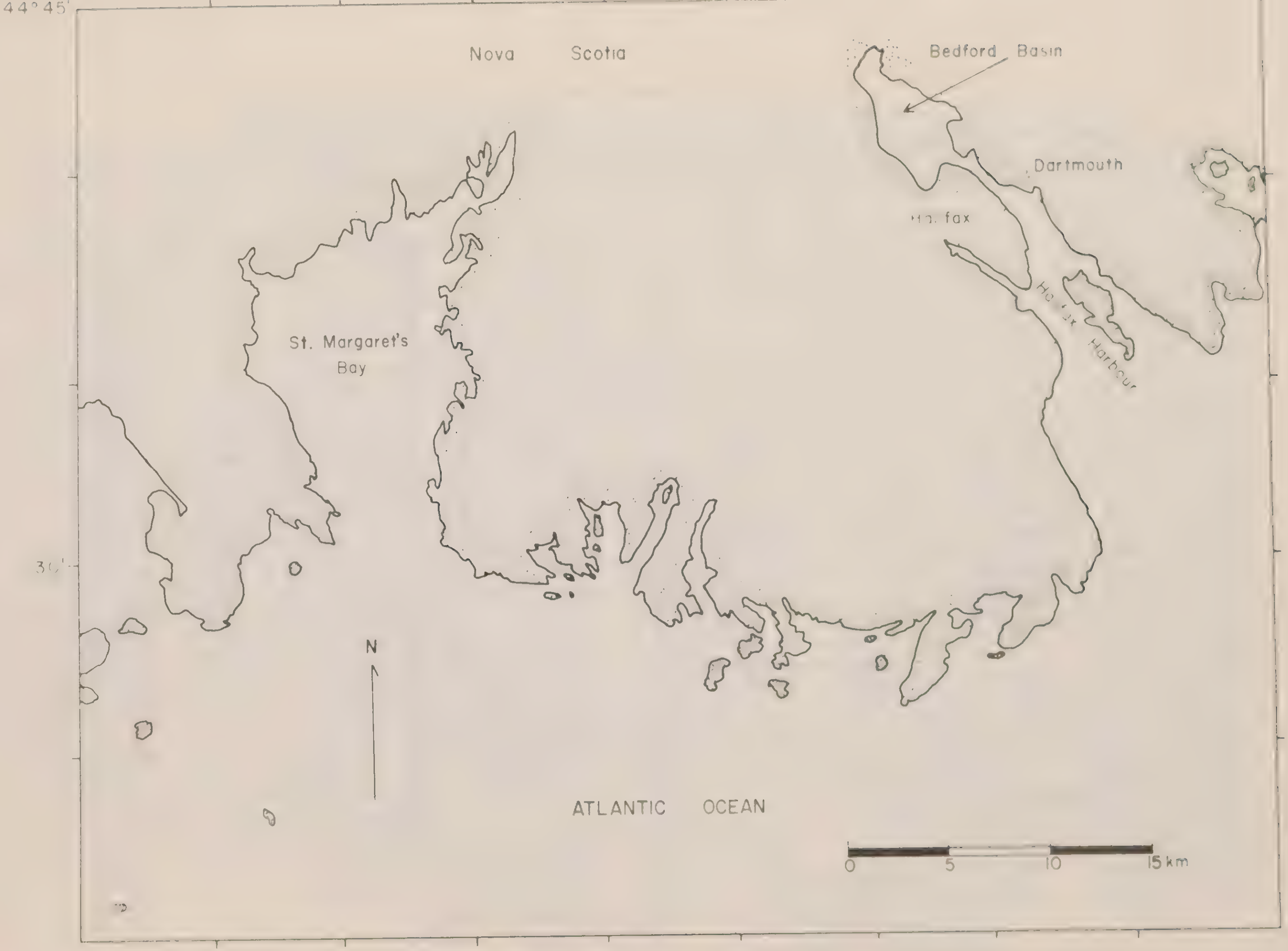

Figure 2. Sketch map showing St. Margaret's Bay, which is virtually unpolluted and in close contact with the waters of the Scotian Shelf, and Bedford Basin which is heavily polluted and connected to the open sea by a narrow channel about 10 km long.

has been going on simultaneously, and we have learned that because of the multiplicity of interactions between the organisms, their environment, and the activities of man this multi-disciplinary approach is essential for any understanding in the kind of depth which might lead eventually to the ability to manage effectively.

It is impossible to review all the work that has been done there, I should like to highlight a few conclusions. The first is that St. Margaret's Bay is about 8 times more productive than the open water of the continental shelf. An index of this productivity is gC/m^2.year fixed in photosynthesis. The world average for continental shelf water is about 100 g/year, fixed by phytoplankton. In the Bay the plankton fixes about 200 g/year, and the seaweed zone fixes about 1750 gC/m^2.year. When this production round the fringe is averaged over the whole bay and added to the plankton production it amounts to more than 800 gC/m^2.year.

A key factor in this high productivity is the upwelling of nutrient-rich water. As organisms die and decay they sink and release nutrients in the deep water. Only when this is brought to the surface can the plants use it. An important way in which this happens is by the estuarine entrainment mechanism. Fresh water from a river flows out from the coast in a surface layer, and entrains, or carries along, perhaps 25 times its own volume of salt water. To replace it, an equal volume of deep, salt water has to flow in at a lower level, and well up to take the place of the entrained water (Fig. 3).

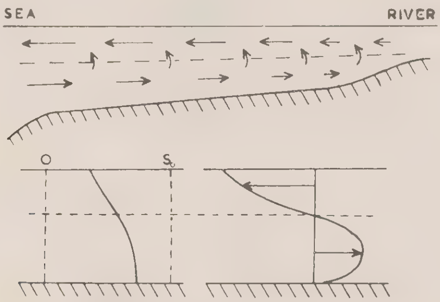

Figure 3. Diagram showing the fresh water flowing seaward at the surface in an estuary, and entraining salt water as it flows. There is a compensatory landward flow of salt water at depth. Typical current and salinity profiles are shown below. From Bowden (1967) (In: G.H. Lauff (ed.) "Estuaries" Am. Ass. Adv. Sci. Publ. No. 83).

Dr. Sutcliffe has calculated that in St. Margaret's Bay more than half of the nitrogen used by plankton and seaweed has to be upwelled in this way. He has also shown for the Gulf of St. Lawrence that there is a very close correlation between the freshwater flow of the St. Lawrence and the productivity of the fisheries. So the first conclusion I should like to mention is:

The flow of rivers into estuaries is crucial to maintaining their high productivity. Interference with their flow, by damming or diversion, normally has a seriously detrimental effect on estuarine productivity.

We have also found in St. Margaret's Bay that at intervals the slow exchange with the coastal waters is augmented by violent exchanges which result from wind action. Dr. Platt has shown that dramatic movements of water, out at the surface and in at the bottom, take place simultaneously in a large number of inlets on the coast when the wind has a certain strength and direction. It has been estimated for St. Margaret's Bay that, in total, the water is exchanged with the outside about 9 times per year. Thus the high productivity which we observed in the Bay not only influences the growth of commercial species within the Bay, but leads to the export of materials to enrich the production of the shelf waters. Young fish are many times more abundant within the Bay than out on the shelf, and many fish lay their eggs in a position where the inflowing bottom current brings the young stages into the rich coastal embayments to pass through the critical early weeks. Another conclusion is: *The coastal embayments, with their high productivity, are crucial to the success of the offshore fisheries. They export large amounts of food material and provide a nursery for young fish. Local pollution in these embayments can impair productivity far out on the shelf.*

Petpeswick Inlet.

Figure 4 illustrates Petpeswick inlet which we studied in the summer of 1971 under the shoreline survey scheme. It differs from St. Margaret's Bay in having large areas of intertidal marsh, and shallow water having rich growths of eel grass. These marshes are also highly productive, but the plant material is not grazed directly. Instead, it dies and decays and is exported as dissolved and particulate organic matter. Studies all along the North American Atlantic Coast have shown that these marshes are about twice as productive as the equivalent area of agricultural land. The material they export is essential to the productivity of the shellfish in the marshes and the young fish in adjacent waters. They also serve as important feeding grounds for wildfowl. Yet, all too often, they are treated as wasteland in need of rehabilitation. The early settlers, especially on the Fundy shore, dyked and drained them for pasture. In urban regions they may be converted to marinas, industrial parks, or dumps for fill. It has been shown that about 60% of the original salt marsh of Nova Scotia has been converted to other uses, and quite recently a considerable area was virtually cut off from the sea by construction of a major highway near Windsor. *It is imperative that the ecological value of salt marshes be recognized and that their destruction or separation from the sea should not be allowed to occur.*

Anaerobic Basins

Near the head of Petpeswick Inlet is a relatively deep basin (26 m) which, after mixing freely in early winter, becomes stagnant all through summer. The organisms in it consume oxygen until by September the bottom is devoid of oxygen and remains so until mixing occurs again in the fall. Very few benthic animals and no fish can live in the anaerobic water, and hydrogen sulphide is generated. Fortunately it does not reach the surface in appreciable quantities.

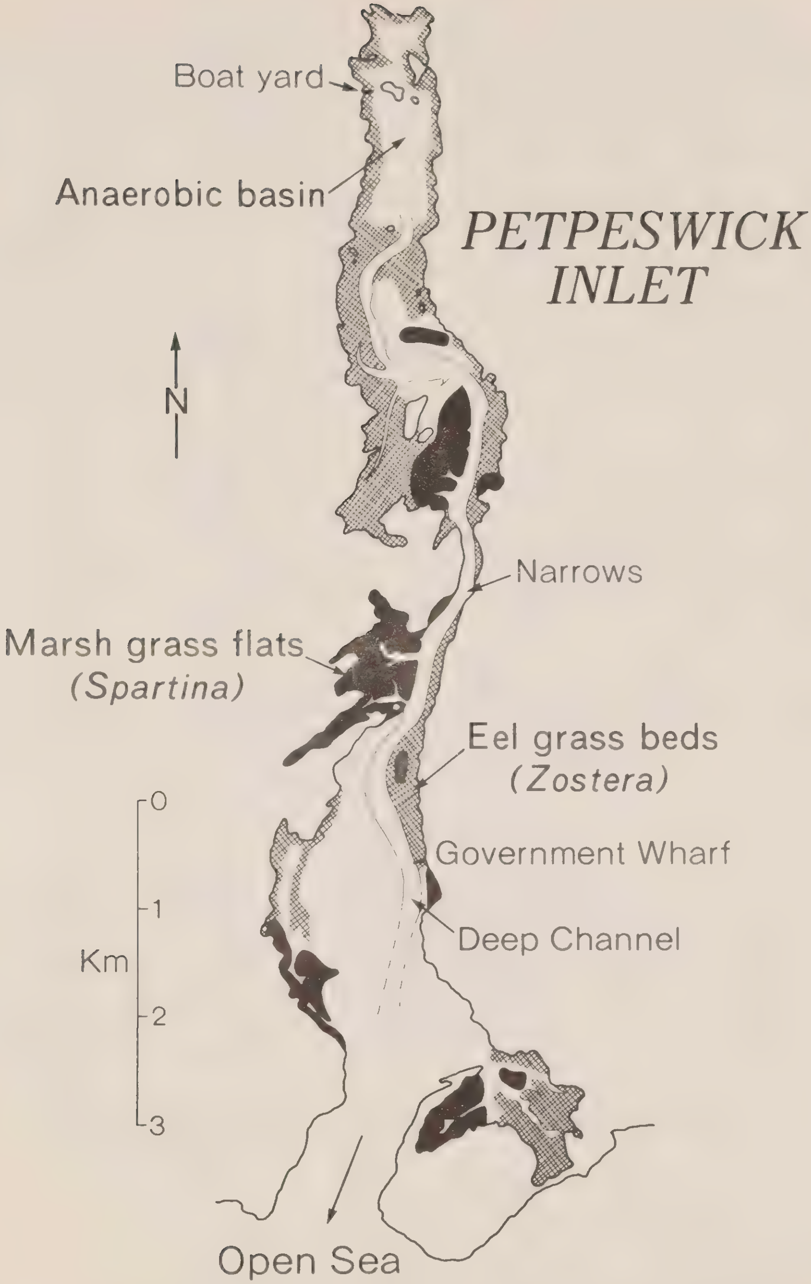

Figure 4. Sketch map of Petpeswick Inlet, showing large areas of intertidal marsh grass and shallow water with eel grass.

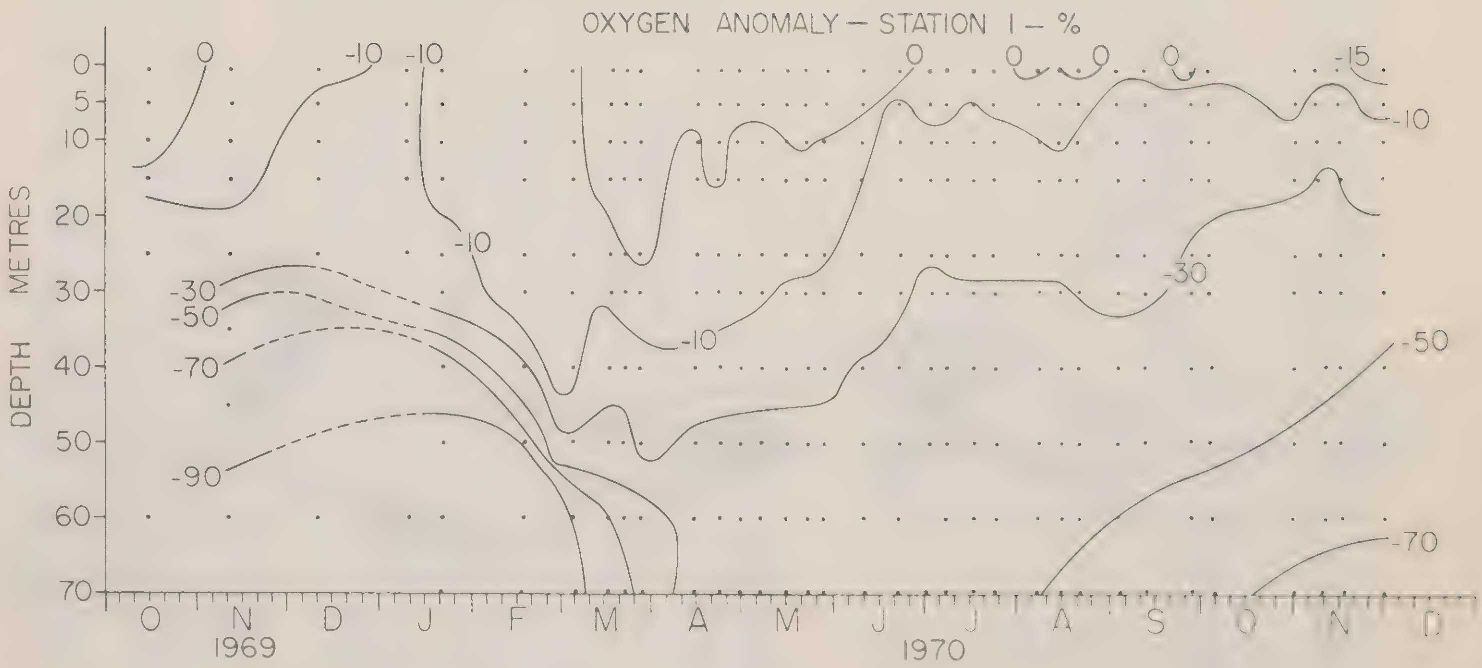

Figure 5. The oxygen anomaly in the centre of Bedford Basin, 1969-70. Numbers against contours are the percentage deficit in oxygen saturation at the prevailing temperature and salinity. From Platt and Irwin (1971) (Fish. Res. Bd. Canada Tech. Rep. No. 247).

Bedford Basin, on which the Institute is located, is a much larger example of the same phenomenon. The basin is up to 70 m deep, but at a depth of 60 m in 1969-70 the water was less than 10% saturated with oxygen from early November to early March. A similar, though less marked decline in oxygen content occurred in the winter of 1970-71 (Fig. 5). Three years earlier, a similar study had shown a much less marked decline in oxygen content.

We cannot say for sure whether the difference between 1967 and 1969-71 indicates a deterioration in the condition of Bedford Basin, or whether the degree of stagnation in a particular year depends on the meteorological and hydrological conditions. We can say for sure that the system is delicately balanced. Large quantities of raw sewage are discharged into the Basin, with a high biological oxygen demand. A deep, anaerobic, intermittently flushed basin is most unsuitable for such discharges, and a combination of poor flushing and increased load of sewage could lead to liberation of large quantities of hydrogen sulphide at the surface, causing considerable discomfort to the citizens and massive mortalities of fish.

Even in its present stressed condition, the basin is making a major contribution to the productivity of the outer waters. A very detailed study of exchange at the narrows, outside these windows, showed that of a day's phytoplankton production occurring in the enriched waters of the Basin, 58% was exported, mainly by the action of tidal flushing. The Basin thus exhibits many of the characteristics of a vast chemostat, receiving nutrients from sewage effluents, and using them to synthesize organic material, much of which is exported.

The principal conclusion from the study of these anaerobic basins is that *marine basins which are relatively isolated from the open sea may have many of the characteristics of eutrophicated lakes and great care should be exercised in using them for the discharge of sewage effluents.*

CONCLUSIONS

By these local examples I have tried to show that the ecological system properties of the coastal zone are major considerations placing constraints on the choice of management strategies available. If renewable resources and recreational and aesthetic considerations were of no consequence it might be possible to manage the coastal zone for transport, industry and waste disposal and ignore the biological consequences. But for a balanced system of management it is essential to have an understanding of the biological properties of estuaries, embayments, marshes, rocky shores and sandy beaches, both in temperate and in arctic conditions.

These ecological systems are extremely complex, and it is clear that for management of the coastal zone we need major investment in ecological studies.

INTER-RELATIONSHIPS OF SEABIRDS AND THE COASTAL ZONE

A SUMMARY REPORT ON SEABIRD RESEARCH

D.N. Nettleship[1]

INTRODUCTION

The coastal zone, that part of the marine region which extends to the edge of the continental shelf, is an endangered zone. By its contiguous relationship to the mainland it is the zone most directly and immediately affected by human activities such as : coastal dredging, mining and drilling, domestic and industrial sewage, thermal pollution, shipping, oil spills, fishing, and toxic chemicals. It is also the zone most critical to the reproduction and survival of many marine-associated bird populations (i.e., seabirds, shorebirds, waterfowl) in that it provides breeding sites (rocky coasts and off-shore islets), food for energy requirements (growth, reproduction, maintenance), nurseries for developing young, and wintering quarters. While pollution of our coastal waters is well known, our knowledge of the effects of this pollution on marine life is meagre. This disparity and the need to check it has been recognized for many years, but the best methods by which to accomplish this enormous task are by no means clear.

Since this conference was planned from its inception as a working conference to result in the formulation of specific recommendations of coastal zone priorities perhaps the most useful exercise I can now do is to review our seabird research program (one of several programs the Canadian Wildlife Service is pursuing which is related to coastal areas) which is specifically designed to establish a firm scientific basis from which questions concerning resource management and the quality of the marine-coastal environment can be assessed.

THE SEABIRD RESEARCH PROGRAM

Seabirds are conventionally defined as being any species which spend long periods away from land and habitually obtain their food from the sea. Species comprising this group show marked differences in life strategems ranging from the utilization of inshore habitats (e.g., cormorants, gulls, ducks) to pelagic habitats (e.g., petrels), and from fish-eating (e.g., gannets, auks) to planktonic feeding (e.g., petrels, auklets). Regardless of specific life-style, however, all seabirds return to some land-base, usually in the coastal zone, in which to breed.

Seabirds are not distributed at random in their marine environment. The greatest concentrations of birds both at sea outside the breeding season and at breeding colonies are, not surprisingly, associated with areas of upwelling water and high productivity. It is therefore obvious that this clumped distribution pattern throughout the year exposes seabird populations to high risk in terms of pollution. That this has in fact already occurred is indicated by some of the many changes known to have taken place in seabird numbers during the last four or five decades.

[1]Canadian Wildlife Service, Department of the Environment, Ottawa

Some species have 'exploded' in numbers as a consequence of man's pollution of the environment. For example, the east coast Herring Gull population has increased by a factor of 15 to 30 in this century, as have other opportunistic species which can feed on various forms of garbage and sewage from human populations (apparently the main causes of gull increases). But in most cases this pollution has had a very strong adverse effect on more specialized colonial species (e.g., auks, terns) as evidenced by marked decreases in the numbers of birds breeding at individual colonies and the complete local extinction of others. The future of many seabird populations in Canadian coastal waters is precarious, especially since pollution from human populations is not likely to stabilize or decline in the near future and extensive areas of the continental shelf and Arctic islands are beginning to be subjected to oil drilling. Thus, it is essential that existing information on seabird colonies be collated and a monitoring system sufficiently sensitive to detect real population changes in bird numbers both at sea and at breeding colonies be developed to establish a baseline from which to measure changes in seabird populations in the future. Not only will this program provide quantitative data on which to base species management policy and decision-making, but it will also serve as a real and important index of environmental quality in the coastal zone.

The Canadian Wildlife Service seabird program separates clearly into three parts: (1) colony inventory, (2) productivity, and (3) distributions at sea.

Colony Inventory

Mapping of known colonies is reasonably complete for the densely colonial seabirds in the Atlantic Provinces (Figure 1), but is very sketchy in the eastern Canadian Arctic (Figure 2). Emphasis in the past has been placed on gannets, kittiwakes, puffins, razorbills, and especially murres. However, present data provides little more than geographic distribution of colonies, species diversity, and numbers within orders of magnitude. The present need is to develop census techniques of sufficient precision to measure real changes in numbers within individual colonies. The overall objective is to establish a baseline for comparison of population changes over long periods, the data essential for the assessment of the effects of human activities upon seabird populations and the marine ecosystem.

Productivity

In addition to studies of the number of birds breeding in individual colonies, detailed information is required on various aspects of the breeding biology of each species, especially adult and pre-breeding mortality rates, reproductive rates, and feeding habits. Effective monitoring of representative colonies and species populations will permit comparisons of breeding performance between populations of the same species in different geographic locations and between different species at the same colony. A thorough knowledge of the productivity of a species is fundamental to assessing the importance of observed changes in bird numbers and other population parameters: rate of recruitment, adult survival, age structure, etc. Combined with estimates of productivity is the far more difficult task of identifying the often complex inter-related cause and effect relationships.

Figure 1. Distribution of known (●) and suspected (◐) major colonies of Fulmars (F), kittiwakes (K), Razorbills (R), Common Murres (CM), and Thick-billed Murres (TM) in the Atlantic Provinces. Total colony size and individual species population size within each colony are given as number of breeding pairs within orders of magnitude.

Figure 2. Distribution of known (●) and suspected (◐) major colonies of Fulmars (F), kittiwakes (K), and Thick-billed Murres (TM) in the eastern Canadian Arctic. Total colony size and individual species population size within each colony are given as number of breeding pairs within orders of magnitude.

Distribution at Sea

Systematic studies of the distribution of seabirds at sea in the Gulf of St. Lawrence, in the western North Atlantic and Arctic waters were organized and initiated jointly by Dr. R.G.B. Brown, Canadian Wildlife Service, and Dr. P. Germain, PIROP (Programme Integre de Recherches sur les Oiseaux Pelagiques), University de Moncton. Quantified observations of seabird occurrence have been recorded by a team of observers on board various Departmental research vessels and other federal shipping and aircraft in areas of concern. Detailed maps are being compiled showing quantitative differences in distribution throughout the year, and correlations with the oceanographic data are helping to clarify aspects of the individual species' ecology. The primary aim is to detect and understand the impact of pollutants and other human activities upon seabird populations, some of which are of international concern, since many species found off Canadian shores originate from transatlantic (e.g., auks, fulmars) and transequatorial (e.g., shearwaters, petrels) breeding areas. In terms of pollution risks, for example, these distribution maps will show where, at a given season, a species is commonest, and from this predict where an oil slick would cause the most damage. Furthermore, once an oil leak has occurred, it is crucial to be able to assess which species and breeding populations have been most seriously affected.

SUMMARY AND CONCLUSIONS

It is impossible to give an accurate prediction of what further impact technological man will have on coastal ecosystems in future years. However, it is reasonable to expect continued development of our natural resources, often in areas only recently believed to be inaccessible, but I feel that we, as civil servants, have an enormous responsibility to ensure that this development is not accompanied by total disregard for, and destruction of, the environment. We must therefore assess what we do not know about coastal ecosystems that is necessary to establish a basis from which economic benefits can be compared with ecological cost. Unless we very quickly proceed with a carefully integrated research program we, as a Department of the Environment, will be unable to provide suitable information as to the present state of our Maritime coastal waters in the future.

The Canadian Wildlife Service seabird program is in a small way attempting to provide this basic information. Quantified data on numbers and distribution of seabirds both at breeding sites and at sea outside the breeding season will provide a baseline on which to assess population changes in the future. Let me underline how preliminary and basic this information is. Ideally, what is required, are data not only on the ecology of seabirds themselves but a thorough understanding of most aspects of energy and nutrient flow through the ecosystem of which seabirds are but a part.

Ecosystems consist of a complex web of multispecies systems which are continuously interacting with each other and with abiotic components of their heterogenous environment. While there are perhaps too many parameters to measure individually, the immediate need is the establishment of an interdisciplinary approach to identify and monitor the essential features of the coastal-zone system. Only in this way can a conceptual model be developed from which the complex cause and effect relationships can be recognized. Moreover, it is imperative that research be designed in such a way that each individual phase can be fitted together at the end of the program. To do otherwise may result in the discovery that the fragmental parts cannot be combined into any meaningful whole. The practicality of the construction of a preliminary ecosystem model for the coastal zone I leave for others to deal with.

PROBLEMS OF MODELLING COASTAL ZONE ECOSYSTEMS

Trevor Platt[1]

Construction of a dynamic mathematical model is a popular, and occasionally useful, method of description and analysis of the mechanistic properties of ecosystems. A notable feature of the real world, which is at the present time exceptionally difficult to handle mathematically, is a high degree of variability, both in time and space. This creates difficulties in the modelling of all types of ecosystems; the problem is particularly acute in the coastal zone.

In this talk I would like to illustrate with examples from Eastern Canada, some aspects of this intrinsic heterogeneity of coastal zone ecosystems as seen from the point of view of someone trying to construct and verify a mathematical model of the *production of phytoplankton* in a coastal inlet.

There are three important reasons why the structure of phytoplankton populations in the coastal zone should be so variable in time and space. We may arrange them in order of increasing time-scale.

(1) There is often strong turbulence in the surface layer of coastal inlets.

(2) There is usually a strong tidal influence.

(3) The waters of coastal inlets may be exchanged frequently with the waters of the continental shelf.

Of these effects, the first two (turbulence and tide) have the greatest effect on prediction of phytoplankton production *in the short term*.

For example, suppose we are studying the capacity of a coastal embayment to accept certain effluents which may stimulate the growth of phytoplankton, and wish to make a continuous dynamic model of the standing stock of phytoplankton in the embayment. Given the boundary conditions of initial biomass, a set of data describing daily meterological and tidal conditions and the rate of nutrient addition, output from the model would be an estimate of the total biomass of plankton in the embayment on each day of the year.

Several important questions arise. What are the important parameters to consider and what kind of variability do they exhibit? Are the fluctuations so great that a useful model would not be feasible?

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[1] Marine Ecology Laboratory, Bedford Institute, Dartmouth, N.S.

What sampling frequency is required to obtain verification data for the model? Are the sampling and measurement techniques of suitable precision? Do all quantities need to be measured with the same precision and frequency? What will be the fundamental time scale of the model and how often should the model be brought back to reality?

Let us now look at some real examples from eastern Canada of spatial and temporal variations in the phytoplankton, to see whether we have any information relevant to these questions about models. The quantity we observe is the concentration of chlorophyll, an index of the abundance of phytoplankton. Using the apparatus shown in Figure 1, which was developed and constructed by the Marine Ecology Laboratory, we can make continuous analog or digital records of chlorophyll concentration from a moving or stationary ship. Figure 2 shows a typical result from the surface layer off the Gaspé coast, where fluctuations in chlorophyll of the order of 30% on a time-scale of a few minutes are common. These are thought to be associated with the physical turbulence field. Figure 3 shows fluctuations in chlorophyll concentration among 80 stations spaced 0.1 miles apart along an axial transect in St. Margaret's Bay, N.S. The amount of variation within the bay is remarkable. In the lower figure, which shows two transects made on successive days, the nature of the temporal variation may also be seen. On the second day, a patch of phytoplankton 15 times as concentrated as background was observed. There had been no suggestion of this the day before. The temperature-salinity structure indicated that quite different water masses were sampled on the two successive days.

We next consider an example of the influence of the tide on chlorophyll measurements at a fixed point. Our data came from the Narrows, the channel connecting Halifax Harbour, N.S., with the Bedford Basin. Two stations, one on the Halifax side of the channel and one on the Dartmouth side, were each occupied every hour for 25 hours (Fig. 4). A five-fold variation was observed in the surface chlorophyll during this short period. These fluctuations combined with the changing tidal current to give an exchange of phytoplankton between waters inside and waters outside the basin which varied continuously through the tide. The amount of exchange is a critical term in any model of primary production in a coastal inlet. It was possible to show that, on this occasion, the influence of the tidal fluctuations was twice as strong as the influence of the mean flow in exchanging phytoplankton between the basin and the harbour.

These variations, although most pronounced at the basin exit channel, are by no means absent from the basin itself. To illustrate this let us look at some contour maps of chlorophyll distribution in Bedford Basin made using the MEL continuous fluorometer system. The data can be collected at a speed of 7 knots, and following the track shown in Figure 5, a map of the chorophyll distribution at one depth in the basin can be prepared in 200 minutes. Figure 6 shows the complex spatial structure which may be found in the basin (5 m depth) during the spring outburst of phytoplankton. There is a four-fold change in phytoplankton abundance along the axis of the basin. Figure 7 shows the changing chlorophyll distribution in three successive runs made on the same day, beginning two hours after low water. On the first run, the most obvious feature was a tongue of chlorophyll-rich water extending from the NE shore to the centre of the basin. On the second run, chlorophyll levels were generally higher all over the basin and the chlorophyll-rich tongue ahd split into two. By the third run, a further general increase in chlorophyll levels was seen, with the two chlorophyll-rich cells still recognisable.

We have seen that the structure of phytoplankton populations is complex, even in a relatively uncomplicated marine inlet. If the complexities were ignored, and a simple, continuous model were constructed, which sought to predict the phytoplankton concentration at some future time, it is difficult to see how the prediction of the model might be verified. A measurement at a single station, which might easily show a 2-fold fluctuation throughout the day, could justify or invalidate the model depending on the time of day the sample was taken.

The other major source of variation in the coastal zone, namely exchange with the waters of the shelf, can affect dramatically the accuracy of short-term prediction of phytoplankton abundance in a coastal inlet: when such an exchange occurs the population observed one day may bear no relationship at all to the population observed the day before.

These exchanges are important in a broader setting however. First, consider the sheer magnitude of one such event; the entire water content of a single inlet may be replaced within a few days. Second, the time constant for the perturbations may be of the order of several weeks. Third, all the inlets on a given coast may be affected simultaneously. Fourth, the properties of the water within an inlet give no clue as to the properties of the water which may replace it if an exchange occurs.

Extensive flushing of inlets, induced by offshore wind is known to occur along the coast of Nova Scotia, particularly in the autumn. For example Figure 8, taken from data in CODC archives, shows a series of stations taken along the coast from Port Medway to Liscomb in the late summer of 1924. The effect of a disturbance on the water structure can be seen clearly. Onshore movement of warm surface waters caused a thickening of the warm surface layer. The increase in thickness was extensive enough to penetrate to the bottom in many of the inlets, causing severe fluctuation in bottom temperatures.

We can illustrate the potential effect of such an event on the production of phytoplankton by looking at changes in the concentrations of inorganic nutrients, essential for phytoplankton growth, in two inlets 35 km apart on the coast of Nova Scotia during 1967. In late September a pronounced change was observed simultaneously in both inlets for each of the three major phytoplankton nutrients, phosphate, nitrate and silicate. These changes have been associated quite definitely with extensive exchange between inlet and offshore water. Thus, not only are the plankton populations themselves replaced, but in addition the conditions for growth are changed in a dramatic manner. This kind of an event is exceptionally difficult to handle in a mathematical model.

In this short paper an attempt has been made to show by means of some local examples how one of the difficulties with all mathematical models of biological phenonema - what to do about the temporal and spatial heterogeneity - is especially important in studies of coastal ecosystems, because of the combined influence of turbulence, tides and exchange of water with the continental shelf zone. The variability may be such as to render inappropriate any attempt at a general systems model of the coastal zone. Instead we should, perhaps, be looking for a general theory of variability in relation to biological production systems. We should be seeking to describe, <u>in the most general terms possible</u>, the response of ecosystems to perturbations on a variety of time scales in the physical environment, and to assess the significance to their overall productivity.

In the long run, this will be the most fruitful approach, not only in terms of contribution to fundamental knowledge, but also in practical terms as a vehicle for reducing the sampling effort required in the continued monitoring which will be an essential element in the program for the responsible management of Canada's coastal zone. The Marine Ecology Laboratory has an active research program along these lines.

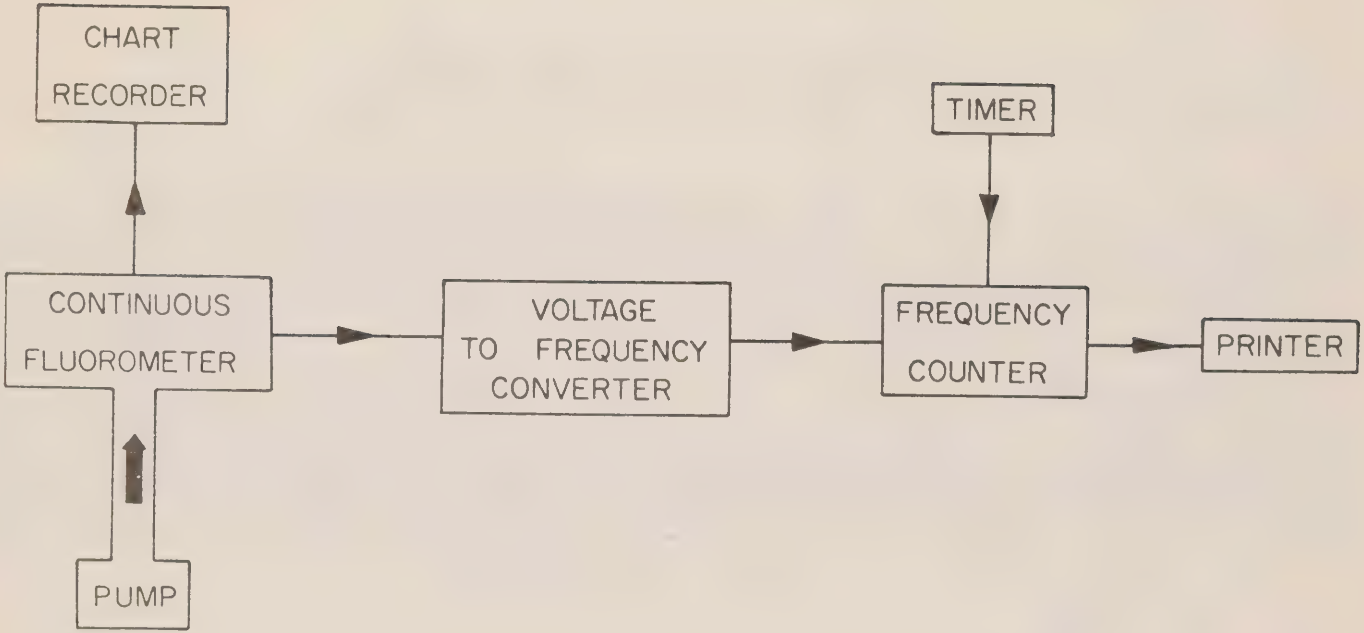

Figure 1. Block diagram of apparatus for studying small-scale structure in chlorophyll distribution automatically.

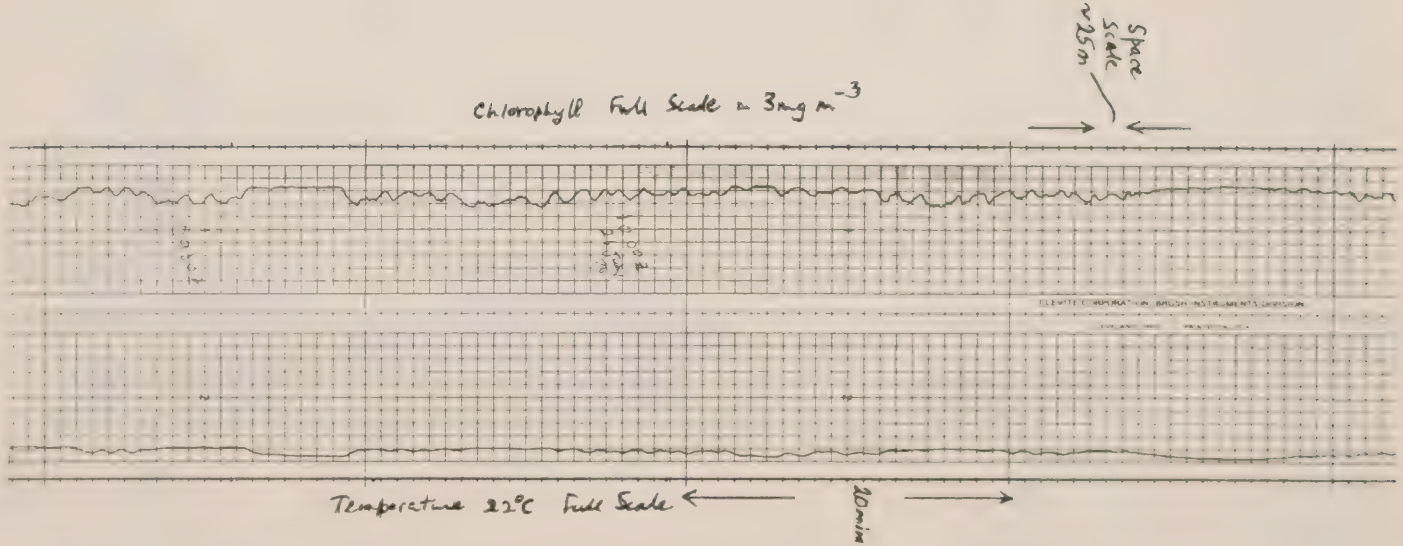

Figure 2. Showing small-scale fluctuations in chlorophyll concentration and temperature at a fixed station on Magdalen Shallows, July 1970. Sampling depth 8m.

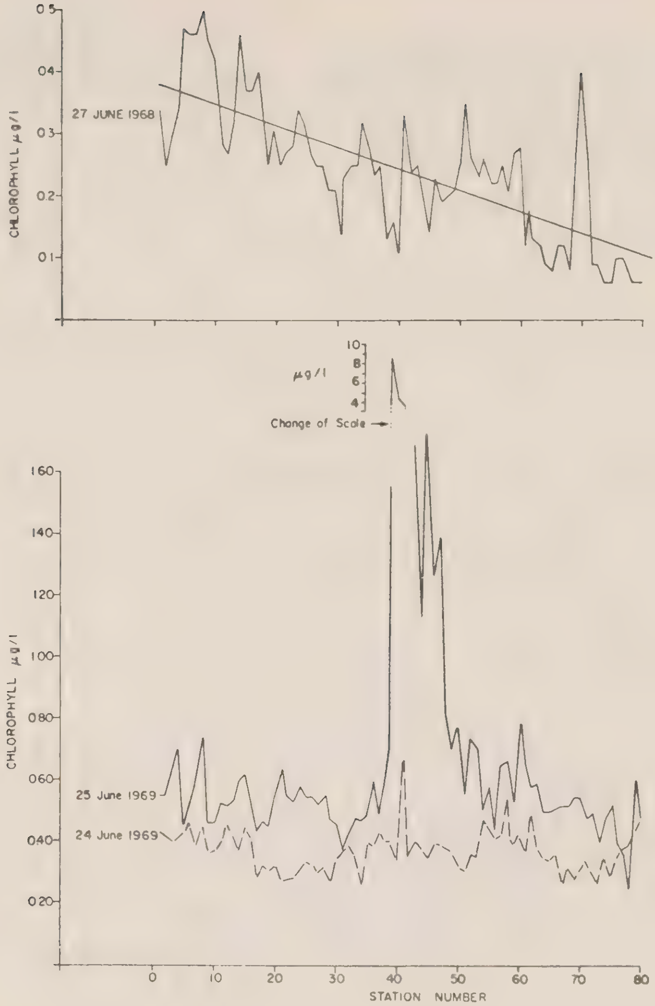

Figure 3. Showing changing chlorophyll concentration at 80 stations on 10-mile transects along the axis of St. Margaret's Bay, N.S.

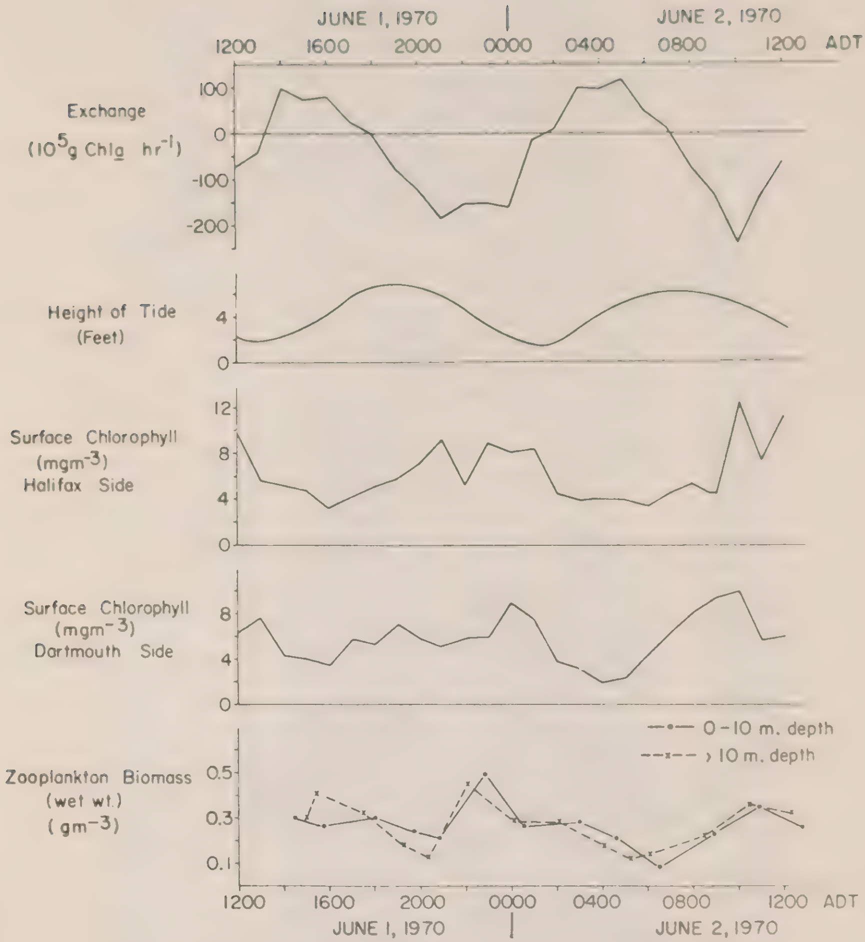

Figure 4. Showing changes in chlorophyll and zooplankton abundance during a complete tidal cycle at the Narrows, between Bedford Basin and Halifax Harbour, N.S.

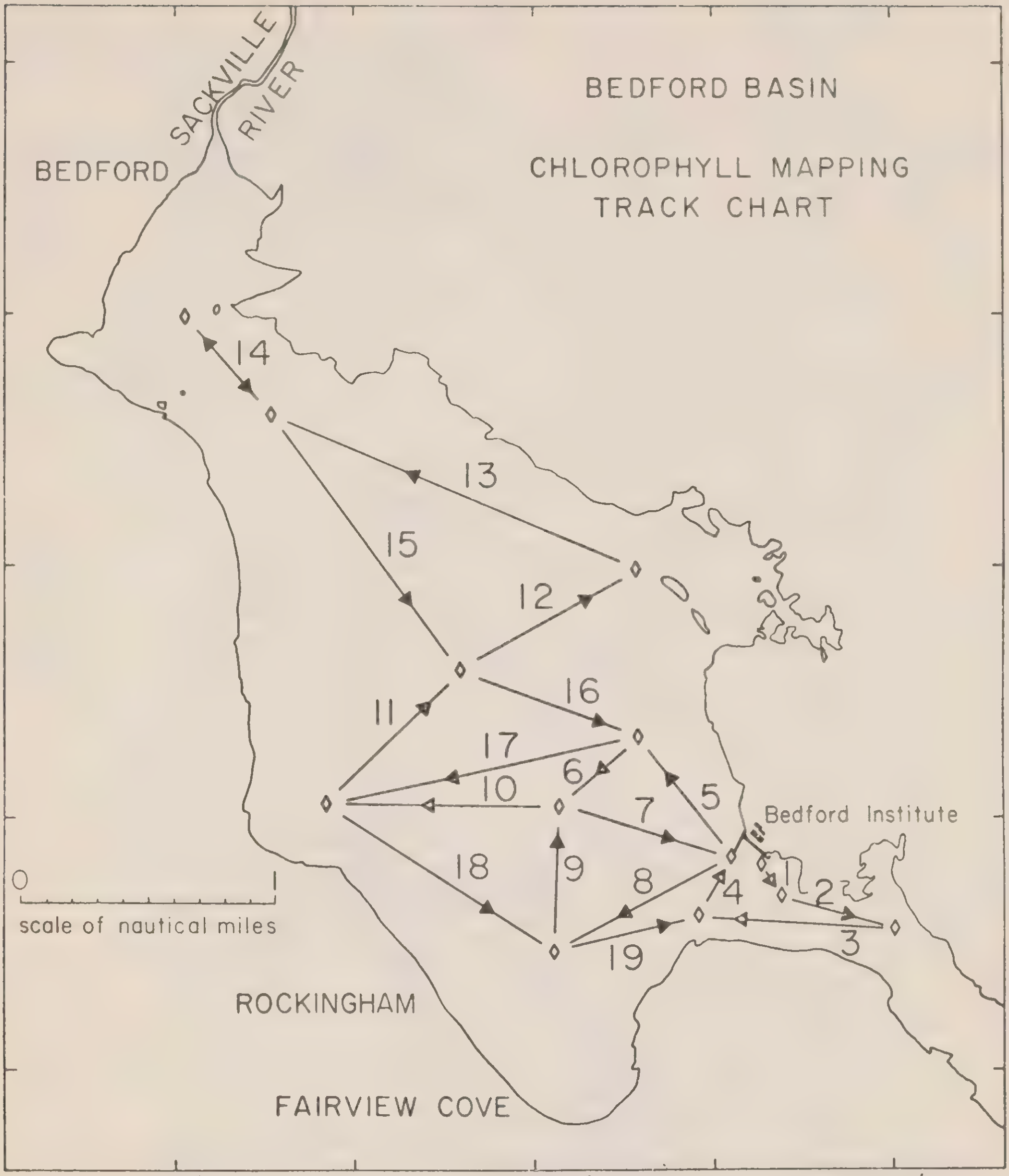

Figure 5. Track chart used for mapping chlorophyll abundance in Bedford Basin.

Figure 6. Example of a map of the distribution of chlorophyll at 5m depth in Bedford Basin. Made during the spring bloom of phytoplankton, 1971.

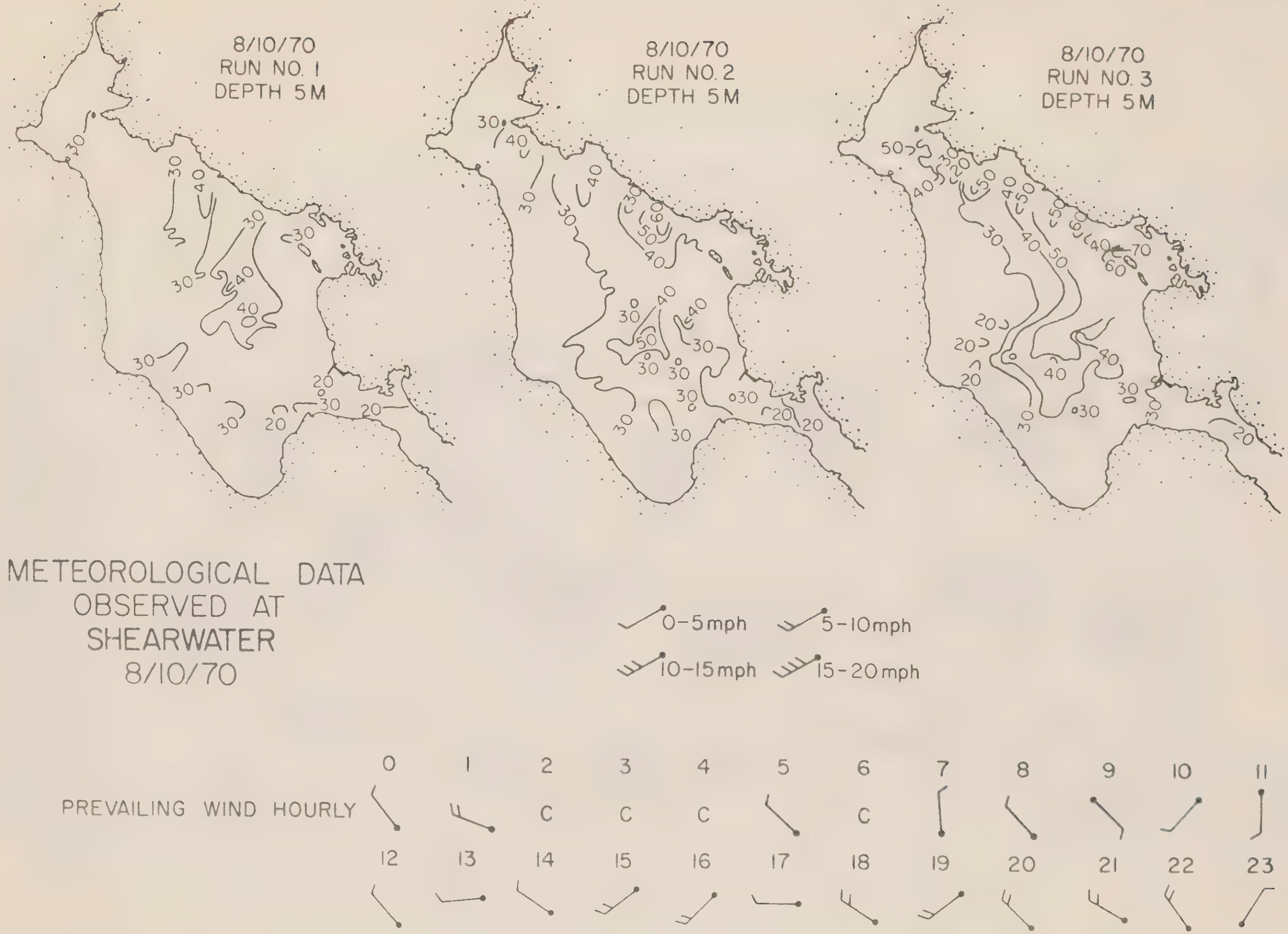

Figure 7. Three maps of chlorophyll distribution at 5m depth in Bedford Basin each made on the same day, one after the other. Total sampling time 7 hours.

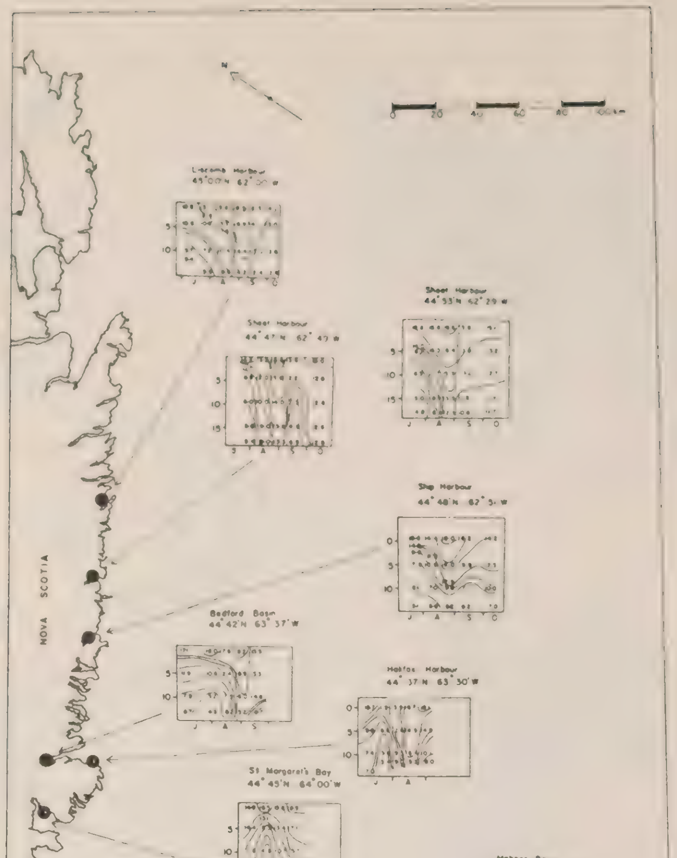

Figure 8. Oceanographic time-sections made at several stations along the Nova Scotia coast in late summer, 1924. Showing the similar influence of an offshore disturbance in the inlets along a considerable stretch of coastline.

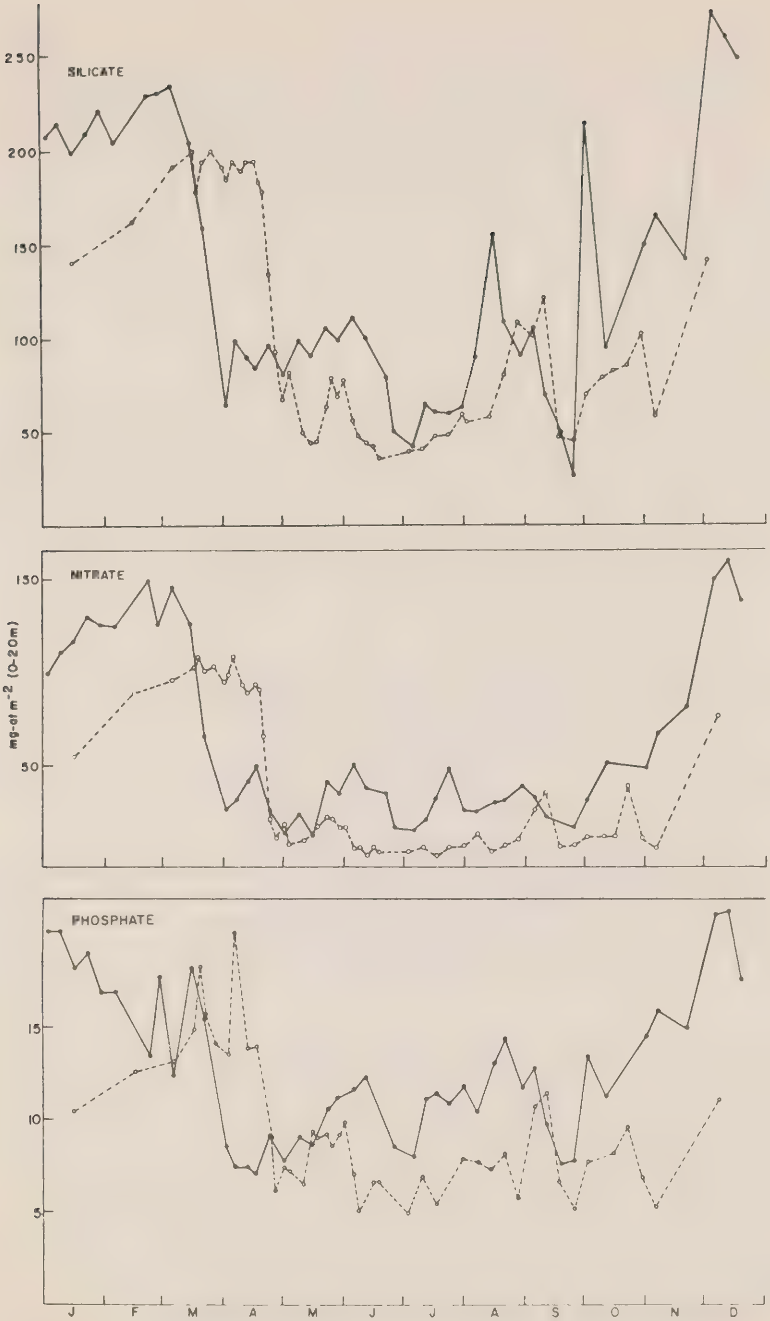

Figure 9. Annual cycle of phytoplankton nutrients in 1967 for Bedford Basin (solid line) and St. Margaret's Bay (broken line).

MAN AND WATERFOWL IN TIDAL SHORELINES OF EASTERN CANADA

Austin Reed[1]
Allan D. Smith[2]

The intertidal zones of estuaries and bays of eastern Canada are of particular interest to the waterfowl biologist. It is in this habitat that many hundreds of thousands of waterbirds find the food they require to produce eggs and raise their young - or to form energy reserves to see them over extensive migrations. Direct or indirect changes in tidal shorelines caused by man are thus viewed by the waterfowl biologist largely in terms of their consequences to bird populations and the recreational opportunities which these birds afford. This paper inevitably reflects this view but an attempt is made to place the problem in broader ecological perspective.

Intertidal ecosystems, although possessing unique biological, chemical and physical qualities, rely on input from marine and terrestrial ecosystems - and in turn influence the functioning of these adjacent systems. Thus direct disruption of tidal ecosystems can have profound effects on marine and terrestrial communities of plants and animals. The case of the tidal marsh - a plant community characteristic of large expanses of our eastern Canadian coastal shorelines - provides a most useful example for this discussion.

Salt and brackish marshes of the Atlantic Coast of North America are characterized by the presence of *Spartina* grasses (*Spartina alterniflora* and *S. patens*). The marshes of the Bay of Fundy and the St. Lawrence Estuary have been described in detail by Chapman (1960) and Reed and Moisan (1971). To fully understand the ecology of these marshes we must rely on detailed studies carried out in Georgia by Odum and his colleagues and in New England by Teal and others.

These studies (Teal 1962, Teal and Teal 1969, Odum and de la Cruz 1967) have indicated the very high rate of primary productivity of Spartina marshes. In terms of weight of organic material produced per unit surface, the Spartina marsh greatly surpasses all other natural ecosystems and matches the production of the most fertile arable land under very intensive management. This high primary productivity is due largely to 1) the remarkable ability of Spartina to capture and utilize solar energy, and 2) regular tidal flooding which provides a constant flow of nutrients and elimination of toxic wastes. Salt marsh production is based on a detritus chain (Odum and de la Cruz 1967) which means that the "food" produced is mainly in the form of small particles of decomposed Spartina and bacteria. Within the marsh production is directly beneficial to the detritus eaters (certain invertebrates and fish) and indirectly on up through the trophic chain to fish, shellfish, birds and man.

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The tidal marsh supports adult populations of several commercially important species of fish and shellfish, and serves as a "nursery" for larval or juvenal populations of many other species. Eastern Canadian tidal marshes annually produce large numbers of Black Ducks (particularly those of the St. Lawrence Estuary - see Reed 1970) which are highly prized by waterfowl hunters. These marshes represent the most important element of the wetland habitat available to the many species of migrating ducks and geese as well as to the hunter throughout the Maritime Provinces and eastern Quebec. To this can be added the many existing and potential values such as outdoor recreation (bird watching - nature interpretation, etc.), esthetics, tourism, etc.

Of still greater ecological significance is the fact that approximately half of the organic production of the marsh is removed by tides and animal activity (Teal 1962, Teal and Teal 1969). Adjacent marine and estuarine communities (and to a lesser extent land communities) benefit greatly from the marsh's bounty. Recently Buckley (1971) has pointed out the extreme importance of tidal marshes near areas of high human population: The marsh serves as an area of depollution through recycling of nutrients from sewage and by providing ample detritus for the abundant bacteria thus amplifying the conversion of urban and industrial wastes into marine resources.

Obviously then man can benefit tremendously from the efficient functioning of this natural ecosystem. Unfortunately this fact is not generally understood and many abuses have resulted from attempts by farmers to dike-in and cultivate portions of tidal marshes. In eastern Canada efforts to turn tidal marsh into non-tidal agricultural land began with the French colonists in the 17th century. Dikes, drainage ditches and water control structures were built to prevent tidal flooding. It is estimated that by 1920 upwards of 80% of the salt marshes of the Maritimes had been "reclaimed" and converted to agricultural production. Falling markets for hay and beef removed the stimulus to maintain dikes and tidal dams (aboiteaux) leading to deterioration and the gradual reversion of some areas into tidal marsh. Today approximately 65% remains diked-in. In Quebec's St. Lawrence Estuary about 32% of the tidal marsh is under agriculture (Reed and Moisan 1971). Urban and industrial development has contributed to a lesser extent to this decreasing acreage of salt marsh. On the remaining marshland, detrimental local operations occur which defy individual evaluation but which globally have a profound influence. These include abusive draining and grazing practices which maintain many acres in salt panne. Heavy silting at the mouths of several streams is resulting from recent programs of "stream improvement" for agricultural drainage on adjacent uplands. Access roads to wharves and fish traps also affect the salt marsh as do municipal dumps, sewage lagoons and insect control programs.

The agricultural value of "reclaimed" tidal marsh is often not great. This is reflected by the many acres of diked lands which now remain idle in the Maritimes. In the St. Lawrence Estuary some lands lie idle and yields are obviously low in most active areas. In this latter area, under intensive management and care the capabilities of the soil may approach those of the adjacent lowland plain. But even these soils are classified as having "moderately severe" to "severe" limitations restricting the range of crops and/or require special conservation practices. (Classes 3 and 4 as shown on the maps of soil capability for agriculture published by the Canada Land

Inventory of the Agricultural and Rural Development Act.) This same inventory classifies the tidal marshes as Class 1S and 2S (lands having no significant or only very slight limitations to the production of waterfowl and also being important to migrating birds).

Mediocre yields in diked areas have undoubtedly provided insufficient incentive to the farmers to care properly for their dikes and water control gates. Despite the obvious results of past efforts, resurgence of diking of tidal marshes is presently occurring. On the basis of interviews with several farmers of the St. Lawrence area we conclude that recent attempts have been stimulated by the availability of heavy machinery which has been placed at the farmer's disposal and for which the government pays the lion's share. Each farmer has the right to a certain number of hours of subsidized bulldozer or power shovel operation. Use of this facility to dike off tidal land appears more a question of "using up" the allotted subsidy rather than a sincere attempt to increase productive surface area. The time consuming maintenance operations required to assure efficient functioning of these structures appear inconsistent with the attitudes and/or ability of the majority of today's farmers - further jeopardizing the likelihood of success of such endeavours. In the Maritimes direct encouragement to continue diking tidal marshes came with the signing of the Maritime Marshland Rehabilitation Act[1] in 1948 (MMRA). This led to the replacement of earlier structures and construction of new ones to collectively protect agricultural interests with sea wall dikes over most large marsh areas.

We might now profitably look at some of the birds which use these tidal marshes and the influence the modifications and deteriorations of tidal marshes has had upon them. For the present purposes we shall restrict our discussion to the ducks and geese although it must be recognized that a multitude of other aquatic birds, wading birds and even terrestrial birds make extensive use of this habitat.

By far the most important factor attracting waterfowl to tidal marshes is the food resources the ecosystem offers. Waterfowl food items which occur in abundance include the seeds of many marsh plants, the tubers of certain plants, insects (both adults and larvae), gasteropods, bivalves and amphipods.

Canada geese are perhaps the most wide spread and prominent of the geese which use the eastern marshes on their annual migrations. Many thousand make lengthy stop-offs, particularly in the spring. Their feeding is divided between the marshes and adjacent grain fields. Brant are also present in very large numbers during spring migration. Perhaps the most spectacular, however, is the Greater Snow Goose. The only known stopping-off point between the Arctic breeding grounds and the wintering area of the Carolina coast, for the entire world population of this sub-species is near the inner limit of the St. Lawrence Estuary at Cap Tourmente. In recent years, more than 100,000 geese have inhabited this area for lengthy periods in both spring and fall.

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[1]The Act provided federal funds for the construction, reconstruction and maintenance of dikes, tidal dams and breakwaters in the three Maritime Provinces over a 20 year period. By the end of the fiscal year 1968-69, a total of 232 miles of dike, 409 tidal dams (5 major) and 20 miles of river bank control installations were constructed in the Maritimes. Federal expenditures amounted to nearly $19,000,000.00 for construction and maintenance, and $9,000,000.00 for engineering and supervision services (Canada Department of Regional Economic Expansion, 1970, pp. 32 and 45).

The tidal marshes which they occupy at that time are fresh water marshes and are characterized by the presence of Scirpus americanus (rather than Spartina alterniflora) and it is the tubers of this plant that form the staple diet of the species.

The most common duck of the tidal marshes during migration periods is the Black Duck. Large numbers of Green-winged Teal and Pintail also use the area during spring and fall migration. Smaller numbers of Blue-winged Teal (Anas discors) and Mallards are also present. These ducks rely almost entirely on the tidal marsh for their food supply. A more typical coastal species of duck, the Common Eider, may also be observed here but it tends to concentrate mainly along non-marshy shorelines.

Only the Black Duck remains to breed in large numbers in these marshes although small numbers of Green-winged Teal and Pintail may also do so. Our detailed studies of the breeding ecology of the Black Duck in the St. Lawrence Estuary have pointed out the great importance of the tidal marshes as feeding areas for nesting adults and as rearing grounds for the broods (Reed 1970).

Although detailed studies of the food habits of all major species has not been undertaken it is nevertheless evident that most of the waterfowl are relying very heavily on food produced by the naturally functioning tidal marsh ecosystem. A "reclaimed" field of hay or oats is of lesser value to waterfowl. Evidence is accumulating to show that even minor modifications of tidal marshes by man (or his domestic animals) can drastically reduce the number of ducks and geese which this habitat supports. It would not be far-fetched to assume that the many other natural "products" of the tidal marsh (fish, shellfish, "nourishment" for adjacent communities, "cleansing" and conversion of wastes, etc.) are similarly affected.

Although an economic evaluation of the potential importance of the eastern Canadian tidal marshes' ecological, recreational, educational, aesthetic and touristic values is all but impossible at this time, it appears to us that these values greatly surpass their agricultural value. The former values exist naturally and require only legal protection for their preservation. Agricultural values, limited as they often appear to be, require vast expenditures of public funds and careful maintenance for their realization.

How then can these conflicting interests be resolved? It will undoubtedly take many years before all the subtle ecological and economical values of tidal marshes will be adequately recognized and acted upon by land developers and planners of the various sectors of society. Progress along these lines could be accelerated by a concerted effort of the ecologists to make these values more widely known. In the populated portions of eastern Canada the problem is nonetheless in the present and more immediate action is required. A program of zoning and easements in agricultural areas could assure the preservation of much tidal land in its natural state, but serious legal considerations hamper such efforts. Land titles to much shoreline property in the Maritimes and in Quebec date from the French Regime and an overwhelming variety of rights to adjacent tidal land is written into many of the deeds. Legal clarification of rights and titles to tidal land must precede any efficient large scale program of easements and/or zoning.

The Canadian Wildlife Service began a program of acquisition of valuable and threatened wetlands throughout Canada in 1966. To date 7 sites have been acquired in the Maritimes and 3 sites in Quebec. Of these, 6

Maritime sites are on coastal lowlands incorporating large acreages of salt marsh and diked marsh, while 1 of the Quebec sites include an extensive area of the tidal shoreline utilized by the Snow Geese in the St. Lawrence Estuary. Two new sites along tidal shorelines are presently under negotiation. The total acreage of these 9 areas of coastal and estuarine waterfowl habitat will surpass 38,000 acres.

This paper has emphasized the impact of human activity on tidal marshes. Other types of tidal shorelines are also important to aquatic birds and in the efficient functioning of estuarine and marine ecosystems. For example, stabilized sand spits and dunelands that are responsible for the natural development and maintenance of coastal lagoons and barrier beach ponds are slowly being destroyed by the hoards of humans who annually flock to the beaches. Dune buggies and similar motorized vehicles severely threaten this environment. Fragile habitat types such as dune land must be scrupulously managed to prevent their destruction.

We have attempted to show that man's abuses along tidal shorelines are felt not only by the waterfowl and the humans who hunt or observe them, but also inevitably by society as a whole.

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SOME COASTAL MAMMALS -

THEIR HABITATS AND STATUS

D. E. Sergeant[1]

I shall define "coastal mammals" as species inhabiting the Continental Shelf, all of which, at the right times and places, may be visible from the coast.

These may be divided into the widespread and abundant pelagic species, most of which are migratory, and the coastal species, mostly resident.

The first category includes those species which are or have been exploited; the great whales on both coasts, harp and hood seals on the Atlantic Coast, northern fur seals on the Pacific Coast.

Of these the Pacific whales have been heavily exploited, mostly by foreign agencies on the high seas, and coastal fisheries have recently ended (Pike, 1968).

On the Atlantic Coast, fisheries for harp and hood seals at the ice-fields have been heavy and restrictions are now in force; notably a ban on fishing by large vessels (over 60 ft) in the Gulf of St. Lawrence since 1972.

East coast whale stocks are fished only by Canada, due to long-time international agreement banning pelagic whaling in the North Atlantic, and lack of interest in shore whaling by the U.S.A. and France (St. Pierre and Miquelon). There is currently one shore station on the outer Nova Scotian coast and two on Newfoundland's east and northeast coasts (Mitchell, 1968). There is no whaling in the Gulf of St. Lawrence. There are quotas for the fin whale, the chief commercial species, and two additional, more oceanic species, the sei and sperm whale are taken. Blue and humpback whales are totally protected. There is a modest fishery in eastern Newfoundland for the small baleen whale, the minke whale, and in this region a stock of inshore-moving pilot whales has been hunted to depletion.

Pelagic seals are not hunted commercially on the west coast under the terms of the long-time agreement with the U.S.A., Japan and the U.S.S.R. Instead, Canada receives a share of the catch taken by the U.S.A. at the Pribilof Islands.

Killer whales are coastal-living in the deep waters of the west coast. The species exists in the hundreds or low thousands in waters around British Columbia and is practically resident. Its diet includes herring and salmon and it was hunted as a pest up to 1963. In that year, the first animal was captured alive for an aquarium. Subsequently, a modest trade developed and nearly 50 animals have been captured alive in the Strait of Georgia and Puget Sound for aquaria in North America, Europe and Australasia. The species has thereby become well known. Recently, controls have been placed on the live-capture trade and the species is otherwise tightly protected.

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A sub-arctic relict population of white whales inhabits the Saguenay area, remaining in the estuary all the year (Vladykov, 1944). The population may number about five thousand. There has been no organized hunting of this population since the 1940's.

The coastal living seals are two in number on each coast. The harbour seal, a species of sheltered waters, lives on both coasts (Fisher, 1952; Templeman et al., 1957). On the west coast it has earlier been subject to a bounty and more recently hunted for its pelt (Bigg, 1969). On the east coast, it is hunted for the bounty, and its numbers have been greatly reduced in the Maritime Provinces and Newfoundland.

On the west coast Steller's sea lion inhabits the outer coast. Its food includes a good deal of herring and salmon (Spalding, 1964). Periodically gunned down as a pest in the past, it is now formally protected except in cases of damage to fishing gear. It is beginning to become a tourist attraction at sites such as the new National Park at Long Beach, Vancouver Island, where there is a non-breeding colony.

On the east coast, the grey seal is a large species which whelps in winter on coastal islands, (Sable Island, two localities off eastern Cape Breton and Nova Scotia) and on ice in Northumberland Strait (Mansfield, 1966). Rare in the 1940's, it was exempted from bounty except in the Miramichi estuary and has since increased to an estimated 17,000 animals. The causes of the increase are not clear but one contribution has probably been the Canso causeway. This may have allowed stagnation and greater formation of ice in George's Bay, a main whelping ground. The young born here mostly drift with the ice round Cape Breton Island, where on the east coast the species causes considerable damage to inshore fishing gear. Control is practised by the Fisheries Service but the ice-breeding groups are relatively inaccessible in the rough ice and poor weather of January.

Lastly, one extirpated species is being reintroduced on the west coast. This is the sea otter, an inhabitant of kelp beds which feeds on sea urchins and abalone. Reintroductions have been made and continue in Washington, Oregon and British Columbia to fill the gap in what was once a continuous range from California through Alaska and the Aleutians to Asiatic colonies. In a few years the species will probably again be a familiar sight off the rocky shores of British Columbia.

It can be seen that there is not now a single exploited sea mammal species on the west coast where in a short eight years the public viewpoint has swung fully from exploitation to protection and aesthetics. This trend is far less pronounced but detectable on the east coast. The increase in the number of coastal parks at such sites as Forillon in the Gaspé will undoubtedly result in greater public appreciation of the coastal seal species and the migratory Cetaceans, which are visible during the summer months from a site such as Cape Gaspé. East coast cetacean species are about 20 in number (Sergeant, et al., 1970). No large populations are needed for this type of "exploitation". In the St. Lawrence estuary in 1970 and 1971, viewing of whales became a tourist attraction from shipboard. Several species (fin, humpback, minke, porpoise and beluga and probably blue and sei whales) may be seen regularly between Rivière Portneuf and Tadoussac and are indifferent to the heavy ship traffic. Viewing of harp seals at the Gulf icefields began in 1972 but cannot yet be regarded as a viable economic proposition, because of the high transportation costs.

It remains to be seen whether this strong shift, in North America, from exploitation to aesthetics of sea mammals represents a permanent trend or an extreme swing. Whether our coastal fisheries in the future consist of exploitation of wild stocks or mariculture, it seems likely that coastal sea mammals will require local controls. The east coast with its short summer and low economic base also seems likely to retain direct exploitation of sea mammal stocks for some years into the future.

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SCIENTIFIC NAMES

Fur Seals and Sea Lions (Otariidae): Northern Fur Seal, Callorhinus ursinus; Steller's Sea Lion, Eumetopias jubatas.

Hair Seals (Phocidae): Harbour Seal, Phoca vitulina; Harp Seal, Pagophilus groenlandicus; Hood Seal, Cystophora cristata, Grey Seal, Halichoerus grypus.

Whales (Cetacea): Whalebone Whales (Mysticeti): Blue Whale, Balaenoptera musculus; Fin Whale, B. physalus; Sei Whale, B. borealis; Minke, B. acutorostrata; Toothed Whales (Odontoceti): Beluga, Delphinapterus leucas; North Atlantic Pilot Whale, Globicephala melaena; Killer Whale, Orcinus orca; Harbour Porpoise, Phocoena phocoena.

Sea Otter, *Enhydra lutris*

Sea Urchin, *Strongylocentrotus drobachiensis*; Abalone, *Haliotis kamtschatkana*.

Kelp, *Nereocystis lutkeana*

Land

NOTES ON LAND USE AND LAND USE PLANNING

A. Beaulieu and J. Maxwell[1]

INTRODUCTION

Six background papers have been prepared for the Coastal Zone Seminar by members of the units brought together to form the Department's new Lands Directorate. The papers deal with the past and current activities of these units as they relate to coastal areas. Mr. W. Black's papers on the coastal city, and ice as an environmental factor are based largely on past research conducted by Mr. Black when he was a research officer in the Water Sector, Department of Energy, Mines and Resources. The papers prepared by Mr. R.J. McCormack and Mr. D. Coombs describe the data systems of the Canada Land Inventory (C.L.I.) and illustrate the potential use of C.L.I. data in coastal zone planning. Mr. Redpath's paper on shore-land ownership and access issues, and this paper, are based largely on past experience of the directorate's Land Use Planning Branch in federal-provincial planning studies conducted in various parts of the Maritime Provinces under the Agricultural and Rural Development Act (ARDA) and the C.L.I. pilot scale land-use planning programs.

Because one of the prime objectives of the Seminar is the development of a greater awareness within Environment Canada of activities related to the coastal zone, the first part of the paper is devoted to a summary description of the land use planning studies in which members of the Lands Directorate have participated. The second part of the paper deals with one particular land-use study of a coastal area. No attempt is made to provide a comprehensive overview of the current status of the use and management of coastal lands at the national or regional level for the simple reason that comprehensive regional studies of coastal land use and management have not been prepared - at least for the Atlantic Region.

FEDERAL-PROVINCIAL LAND USE STUDIES IN THE MARITIME PROVINCES

As part of a program to encourage the application of C.L.I. data in land planning, federal funds were made available to the provinces in the late 1960's for conducting pilot-scale land-use planning studies on the condition that C.L.I. land capability and present land use data would be utilized in the studies. All three Maritime Provinces took advantage of the program and initiated studies covering all or parts of their provincial territories.

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[1]Lands Directorate, Department of the Environment, Ottawa

Prince Edward Island and New Brunswick launched "macro land-use studies" to examine the use and capability of all lands within the respective provinces. In addition, more detailed land-use studies were conducted in the Tantramar Marsh area, N.B. and the Alberton-O'Leary area of West Prince County, P.E.I. Nova Scotia used the program to conduct studies in the Musquodoboit Valley of Halifax County and the Northumberland Strait shore area (Nova Scotia's "Northshore"). Although these studies were concerned primarily with land-use adjustment issues, particularly farm adjustment problems, the methodology developed in these studies has some relevance to land-use planning in coastal areas.

Similar methodology was applied in all of these studies. The initial step involved an analysis of the C.L.I. land capability maps for agriculture, forestry, outdoor recreation and wildlife (ungulates and waterfowl). These maps provide capability ratings in a seven class system for each of the respective resource uses. They enable areas with high, medium and low physical capability for supporting particular classes of land-based activities to be identified. By correlating the resource sector capability maps of an area through a map-overlay process, it is possible to produce an integrated capability map showing tentative prime and secondary use designations for land units within the study area. These use-designations, however, are only valid in terms of the land's physical capability to sustain the specified uses. When the integrated capability map is correlated with the C.L.I. present land use map for the study area, it is possible to identify areas where land use adjustment may be desirable.

These steps enable the constraints and opportunities posed by the physical determinants of land use to be identified and assessed; they also permit an analysis to be made of the degree to which current land use is in harmony with the physical character of an area. They do not, however, enable the socio-economic determinants of land use to be assessed when assigning use-designations to land parcels.

Socio-economic factors play a major role in the development and evolution of land-use patterns; they are the principal operative forces behind most land-use conflicts and land adjustment problems. These factors must be assessed before "final" prime and secondary use designations can be assigned to individual land units at a given point in time, and before an "indicative land use plan" can be formulated for an area.

A detailed discussion of the many social, economic and technological variables influencing the use of the land is beyond the scope of this paper. Suffice it to say that such basic variables as population growth, disposable income, leisure time, transportation technology, consumer preferences or the competitive position of a region's resource-based industries in national and world markets, can and do play fundamental roles in determining the demand registered by land-using activities for particular locations and types of land. These same variables largely determine the supply of land that is made available to land-based activities. Major changes in these variables, particularly those of land duration, can induce fundamental transitions in regional and even national land use patterns. The mechanism that organizes and integrates the impact of most, but not all, of these numerous variables on land use in the land market. It is here that the price or value of a land parcel, and usually its use, are determined. The land-use planner must be familiar with the land market in his planning area and be in a position to anticipate its potential reaction to major changes in public policies affecting land use.

When formulating his recommendations on the use-designations for specific land parcels, the land-use planner is given additional guidelines concerning the socio-economic factors affecting land use by the basic objectives and strategies specified for the planning exercise. To be successful, all planning studies must have a clearly defined purpose and a set of operational objectives. These objectives should be formulated and selected only after an understanding is gained, among other things, of the role played by the numerous factors affecting resource use within the planning area. This is true for both the simple town plan or the complex regional development plan. An example of the latter is the P.E.I. Development Plan.[2] The basic development objectives for this plan include a major increase in the province's agricultural output and a greater contribution to the province's economy from tourism. These objectives represent significant guidelines to the land-use planner. They suggest to him that he must place a higher priority on the allocation of lands to activities supporting agriculture and tourism than would have been given without these guidelines.

Given knowledge of an area's physical character, land capability and accessibility, plus an understanding of the current and projected demand factors associated with the land resource within the planning area, the planner concerned with an area of Crown land can prepare an "indicative land use plan" that has a fair probability of being implemented successfully.

This plan will show the area use-designations assigned on the basis of land capability and a highly aggregated and generalized analysis of the socio-economic determinants of land use to assess, for example, how much land must be reserved for recreational purposes to meet expected demand. An indicative land-use plan developed on this basis can be an effective guideline when attempting to achieve the "highest and best" use, including the multiple use, of public lands. Such plans, however, stand little chance of being implemented in areas dominated by a multitude of small private holdings.

In regions like the Maritimes, where most of the land is in private ownership (P.E.I.: 94%; N.S.: 75%; N.B.: 55%), it is the operation of the land market and the decisions made by thousands of private landowners concerning the use or disposition of their lands that largely determine the pattern of land use and the quality of land management practices. In addition to knowledge on land capability and general demand factors, an understanding of the private landowner and his land management behaviour is required if realistic land use plans capable of successful implementation are to be formulated for areas characterized by small private holdings.

The way in which the private landowner uses his land depends on several factors. Among the important ones are the owner's <u>motives</u> for holding land (he may hold land for economic or non-economic reasons), his <u>perception</u> of the demand/supply conditions for lands similar in type and location to his holdings, and his financial and technical capabilities for developing his land holdings.

In order to identify and assess those socio-economic characteristics of landowners that affect the use and management of private lands, major landowner interview programs were conducted in the Prince Edward Island and

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[1]In March, 1969, the Federal Government and the Government of Prince Edward Island signed an agreement under the Fund for Rural Economic Development Act (FRED) enabling a 15 year federal-provincial program for social and economic advancement in P.E.I.

Nova Scotia land use studies and the study of the Tantramar Marsh in New Brunswick. Some socio-economic data on landowners are provided by the census; however, these data do not permit a detailed correlation between land-ownership characteristics and land capability.

To enable these analyses to be made, property maps were prepared of the study areas showing all properties five acres or larger in site. This was a large undertaking because in many areas of the Maritime Provinces, the only cadastral maps available are the original Crown grant maps. In the case of Prince Edward Island, property maps were compiled for the whole province. After the properties had been mapped, their owners were interviewed to obtain information on variables such as the age, sex, education and occupation of the owner, number of persons in the household and their age, sex, education and occupations, total household income by source, land use and improvements, land management problems, and future plans of the landholdings. With these data in hand and computerized, it was possible to relate, on an individual land parcel basis, the C.L.I. data on land capability and land use to the socio-economic data on landowners.

An example of the type of information that can be produced from the data system is given in Table 1.

It is possible with this integrated data system to assess the socio-economic significance of current land-use patterns and to anticipate what and where changes may occur in the existing land-use patterns with modifications of existing policies or the introduction of new policies affecting land use. It is also possible to assess the impact of these policy changes on specific groups of landowners.

The land-use planner, when equipped with such a data system, can make final recommendations on the use-designations for all lands within the planning area and formulate proposals for guiding land development (e.g. zoning ordinances, subdivision controls and building codes). These recommendations can be incorporated in the indicative land use plan.

A final note on the land use plan should be made. Unlike the physical determinants of land use, the socio-economic factors affecting land use are very dynamic. Changes in social, economic and technological conditions will create a change in what is considered to be the "highest and best use" for a given land unit at different points in time. To remain valid, the land use plan must be reviewed and updated at frequent intervals. If this task is to be done effectively, land-use planning must be a continuous and iterative process capable of responding to, and dealing with, the flow of changes generated by the basic factors affecting land use. The land market, alone, cannot be relied upon to resolve land use adjustments for it is a highly imperfect mechanism that deals almost exclusively with <u>private</u> costs and benefits. If <u>social</u> costs and benefits are to be considered, then the market mechanism must be supplemented and guided by land use plans.

THE TANTRAMAR MARSH AREA, NEW BRUNSWICK: A CASE STUDY

The tidal marshes of the Tantramar area, which are located at the head of the Bay of Fundy, cover 22,000 acres of land. They form the largest single block of marshland in the Maritimes. As early as 1672, the Acadian settlers, who first reclaimed these lands for agriculture, undertook the

TABLE 1 *

Property acreages and ownership data

Lot no.	Total acreage of owners interviewed	Total improved acreage	Improved acreage as per cent of total	Total acreage rented-in	Number of owners interviewed	Average No. of acres per owner	No. of undivided estates
1	24576	8424	34.27	2427	254	96.75	24
2	16524	5823	35.23	1400	192	86.06	16
3	18801	6954	36.98	1222	147	127.89	5
4	21831	11469	52.53	745	192	113.70	19
5	17738	8553	48.21	306	150	118.25	5
6	17713	8961	50.58	784	166	106.70	14
7	17408	9250	53.13	60	118	147.52	28
8	19055	8126	42.64	1092	136	140.11	8
9	13666	5924	43.34	735	97	140.88	4
10	11291	2998	26.55	330	78	144.75	4
11	14540	2898	19.93	727	131	110.99	4
12	14403	3124	21.68	549	131	109.94	3
13	19807	10487	52.94	511	159	124.57	2
14	16970	9578	56.44	1130	127	133.62	3
15	10253	3410	33.25	431	96	106.80	8
16	14925	8453	56.63	842	109	136.92	4
17	12079	6824	56.49	736	117	103.23	6
18	28051	15503	55.26	313	178	157.58	5
19	15953	13059	81.85	520	143	111.55	3
20	15047	12314	81.83	76	125	120.37	4
21	14808	10812	73.01	222	123	120.39	4
22	14486	9167	63.28	102	102	142.01	3
23	19695	13486	68.47	42	175	112.54	5
24	13475	10750	79.77	45	135	99.81	4
25	14804	12214	82.50	277	103	143.72	3
26	16548	12695	76.71	56	102	162.23	5
27	16665	11021	66.13	202	126	132.26	4
28	20400	14818	72.63	389	135	151.11	4
29	16782	12649	75.37	50	137	122.49	
30	14689	7315	49.79		125	117.51	3
31	18082	13994	77.39	160	172	105.12	4
32	9728	7707	79.22	147	89	109.30	4
33	15462	11666	75.44	203	140	110.44	6
34	16659	10385	62.33	196	136	122.49	4
35	11393	6440	56.52	467	99	115.08	6
36	16362	7330	44.85	763	124	131.95	4
37	14574	6353	43.59	1159	95	153.41	4
38	18552	7038	37.93	968	118	157.22	4
39	13484	5647	41.87	335	123	109.62	7
40	16908	8766	51.84	550	107	158.01	5
41	15350	6958	45.32	402	107	143.45	14
42	10768	3088	28.67	915	75	143.57	7
43	12308	4740	38.51	846	128	96.15	14
44	14128	5644	39.94	540	99	142.70	10
45	13874	5176	37.30	394	95	146.04	8
46	10321	3586	34.74	442	73	141.38	
47	15956	6399	40.10	1007	118	135.22	5

*Example of data produced from the Prince Edward Island Landowner Interview Program

TABLE 1 (Cont'd)

Propertry acreages and ownership data

Lot no.	Total acreage of owners interviewed	Total improved acreage	Improved acreage as per cent of total	Total acreage rented-in	Number of owners interviewed	Average No. of acres per owner	No. of undivided estates
48	19127	10435	54.55	942	179	106.85	13
49	19489	10155	52.10	1275	146	133.48	8
50	19196	13149	68.49	591	144	133.30	10
51	17722	8172	46.11	392	101	175.46	4
52	17473	6933	39.67	553	116	150.62	8
53	14030	3654	26.04	286	102	137.54	9
54	13554	4737	34.94	762	84	161.35	1
55	18086	5574	30.81	642	148	122.20	8
56	12188	4443	36.45	1953	90	135.42	10
57	19905	11857	59.56	102	184	108.17	8
58	13227	4224	31.93	103	94	140.71	6
59	18410	7161	38.89	245	157	117.26	9
60	12482	3062	24.53	270	91	137.16	8
61	17568	5995	34.12	89	184	95.47	10
62	16071	2635	16.39	274	131	122.67	3
63	18312	5590	30.52	769	187	97.92	10
64	17682	6905	39.05	384	188	94.05	18
65	13940	10278	73.73	372	131	106.41	4
66	4864	2708	55.67	10	28	173.71	
67	21962	13193	60.07	86	153	143.54	6

Income of landowners (nearest $100) *Intentions of farmers*

Lot no.	Total farm income	Average farm income per improved acre	Total forestry income	Total fishing income	Total welfare income	Total non-farm income	Per cent who wish to continue farming	Per cent who wish to abandon farming	Per cent undecided	Per cent unanswered
1	216700	25.72	6200	305000	248900	1095000	71	18	9	2
2	202900	34.84	8000	80600	168400	623000	72	15	8	5
3	457900	65.84	3000	51100	140800	463600	65	7	27	1
4	543600	47.39	14100	32500	151200	576700	69	23	7	1
5	344100	40.23	1400	39100	112700	407100	72	13	12	3
6	574200	64.07	1600	11100	139900	385100	69	11	18	2
7	603300	65.22		58200	73000	219900	65	17	16	2
8	421000	51.80	6500	83900	109300	409600	69	15	13	3
9	256600	43.31	4200	4100	95600	286000	85	12	2	1
10	95700	31.92	2100	27600	78200	178000	59	23	9	9
11	29200	10.07	400	92800	121100	457800	67	22	5	6
12	83900	26.85	1000	57900	128300	447300	50	47	1	2
13	393600	37.53	400	10200	112100	392000	65	22	6	7
14	525900	54.90	4600		137100	387300	34	60	5	1
15	92700	27.18	4500	23300	143600	351600	37	57	3	3
16	488400	57.77	700	15600	134300	392200	40	43	6	11
17	442700	64.87	5000	8100	110400	477700	50	44	5	1
18	1051200	67.80	800	26900	135600	442600	70	17	13	0
19	899000	68.84		1000	114800	387300	87	6	6	1
20	633100	51.41	1200	5100	77300	291300	78	8	11	3

TABLE 1 (Cont'd)

	Income of landowners (nearest $100)						*Intentions of farmers*			
Lot no.	Total farm income	Average farm income per improved acre	Total forestry income	Total fishing income	Total welfare income	Total non-farm income	Per cent who wish to continue farming	Per cent who wish to abandon farming	Per cent undecided	Per cent unanswered
21	496200	45.89	100	42700	83000	393300	63	10	26	1
22	486500	53.07	2100		64000	200200	75	17	5	3
23	720800	53.44	200		133500	395200	77	10	9	4
24	483900	45.01		800	126000	333600	91	3	5	1
25	1163400	95.25	500		53200	240400	86	5	6	3
26	1082500	85.26			50200	186100	74	16	5	5
27	888600	80.62	300		86200	302500	73	19	6	2
28	1427200	96.31		900	99300	336700	85	7	7	1
29	611700	48.35	1700	1000	87000	310500	71	25	4	0
30	284800	38.93	2800	2100	101100	347200	62	29	6	3
31	839200	59.96	400		87800	362600	82	12	5	1
32	544400	70.63	300		45900	211400	74	12	8	6
33	928400	79.58	1700		83700	432300	78	18	4	0
34	802600	77.28		8000	81300	426000	54	32	10	4
35	232100	36.04	1900	29100	81700	279600	59	32	5	4
36	202600	27.60	6800	2300	103400	306700	63	25	8	4
37	207200	32.61	5900	42600	59600	269900	52	41	5	2
38	356400	50.63	10000	6000	66200	299500	75	15	1	9
39	185500	32.84	2200	26600	97000	319600	54	25	5	16
40	343200	39.15	6800	300	73500	222200	70	8	16	6
41	258600	37.16	12200	50400	99600	254400	61	7	18	14
42	169800	54.98	4700	20600	71400	195700	80	9	3	8
43	195400	41.22	13600	45900	121900	359000	29	56	6	9
44	219800	28.94	19100	39200	88500	288500	49	12	14	25
45	275500	53.22	8000	13100	56000	213600	58	24	9	9
46	262400	73.17	17600	50200	65100	210500	51	44	4	1
47	453000	70.79	1900	113200	89500	369800	49	39	7	5
48	790000	75.70	700		137400	565600	81	12	2	5
49	442400	43.56	9200	1200	109600	470800	67	23	7	3
50	1001200	76.14	2200		94400	315800	82	10	3	5
51	526300	64.40	4900		99400	267100	66	27	1	6
52	180600	26.04	6200	2000	109400	384000	49	44	3	4
53	153500	42.00	20500		86200	337100	70	16	10	4
54	122300	25.81	14400	28100	61600	190200	71	14	10	5
55	220400	39.54	12400	114500	114900	372200	71	11	5	13
56	154000	34.66	16000	58900	118100	288300	65	6	21	8
57	598700	50.49	18700	15 000	140800	350200	75	16	4	5
58	128000	30.30	19600	10200	77000	270700	68	28	1	3
59	340800	47.59	8200	10500	110000	441700	64	20	3	13
60	112700	36.80	19800	15900	86000	321100	63	32	1	4
61	153000	25.52	3100	87900	167400	519100	77	13	4	6
62	147800	56.09	17000	31600	157600	482800	62	33	4	1
63	177900	31.82	15600	182400	182400	643400	80	17	2	1
64	523800	75.85	5600	158200	177300	686500	73	18	5	4
65	361600	35.18	700	10300	100200	316500	84	11	4	1
66	212500	78.47	500		28300	56600	75	18	0	7
67	649900	49.26	5300		122500	420500	73	18	9	0

construction of a series of dykes along the foreshore and built a number of dams across the mouth of the streams to prevent the marshes from tidal inundation. By the middle of the 19th century, the Tantramar marshes had become a prosperous agricultural area, producing hay as a cash crop for horse-drawn transport in the growing cities on the Atlantic seaboard. Over the next hundred years, the hay markets declined and there was a corresponding decline in the Tantramar's agricultural economy. The period of decline was accompanied by deterioration of the dykes. The conditions of the dykes had deteriorated so badly by the early 1940's, that an emergency program of construction and reconstruction of the network of dykes, dams and break-waters was necessary. This program was continued under the Maritime Marshland Rehabilitation Act of 1948.

In 1967, the owners of Tantramar marshlands appealed to the New Brunswick Government for additional improvement works. However, before considering further expenditures for reclamation works the Province felt that more detailed information on the viability of land-based enterprises in the area was required. An indication of the land development possibilities was also necessary.

At the request of the Province, an interdisciplinary study group was formed by the Atlantic Office of ARDA to assess land use in the marsh. The following account is based on the study report produced by the study team.

The Physical Framework

Examination of the physical environment of the Tantramar marshlands and adjacent uplands, and an assessment of the physical development possibilities were based on information derived from the C.L.I. capability maps and data obtained in special surveys.

The potential of the land for a number of uses such as forestry, agriculture or wildlife was first evaluated. The analysis revealed an overall low capability rating for commercial forestry production and for outdoor recreation. However, a few lakes exhibited potential for boating and angling; also located within the study area, are two historical sites: Fort Beausejour and Fort Lawrence.

The evaluation of the physical potential for agriculture indicated that 35% of the study area had a capability rating of class 3 for agricultural production. With good management practices, reasonable yields can be obtained from these lands.

The only other resource of significant development potential consists of marshland areas possessing high potential for waterfowl production. These areas were of particular importance, because of their location; they are on one of the major lanes of the Atlantic migratory bird flyway. In fact, the name of the marsh itself is derived from the French "Tintamarre" referring to the noise created by the flocks of migratory birds.

The Land-Use Pattern

The examination of the land-use pattern in relation to the physical potential of the area for different types of uses revealed the great influence of the land's physical characteristics on man's activities. For example,

the physical capability of the area for commercial forest production is relatively low and, although 50% of the farm acreage is forested, the woodlots have a very low priority in the owner's esteem, and forest products account for a very small percentage of the total income of the area. On the other hand, it was very early in history that the agricultural potential of the area was recognized and most of the land which has been farmed consists of lands with the highest agricultural capability rating in the area (class 3). Most of the farms are small-scale enterprises and derive their main income from the cash sale of beef, dairy products and hay. Further analyses revealed that no pressure for additional agricultural land exists in the area. In fact, of the 31,000 acres of cleared land located in the marsh and surrounding upland, only 11,800 were used regularly for agriculture. A considerable portion of the cleared land is idle or has been abandoned.

The only land use conflict of any significance involves lands with high capability for both agricultural and waterfowl use. Part of the acreage with high potential for waterfowl has been put under cultivation, thus reducing in size the original waterfowl habitat. In order to provide guidelines for dealing with this land use issue, the general demand factors affecting agriculture and the socio-economic characteristics of the landowners were assessed.

Property boundaries of all holdings five acres and larger were plotted on air photographs in the field with the assistance of local residents, and at the same time ownership of the land was recorded. The final property map at a scale of 4 miles to 1 inch provided a picture of the land tenure pattern within the area.

Examination of the property map showed the existence of a high degree of fragmentation as well as dispersion of the land holdings. For example, several landowners of the area owned more than 20 parcels of land scattered over a radius of several miles. Apart from the time wasted in travelling between scattered holdings, many parcels were too small to permit efficient use of modern farm machinery.

The landowners were then interviewed to determine their socio-economic characteristics, and the interview data were used to develop an owner classification.

All landowners of the area were grouped in one of six categories according to their age and socio-economic status. The main groups of landowners were defined as follows:

- Commercial farmers (Gross crop, livestock and woodlot income of $3,750 or more per annum - no age limit)

- Non-commercial farmers (Gross crop, livestock and woodlot income less than $3,750 per annum - agriculture major source of income - owner less than 60 years of age)

- Non-farmers I (Non-farm income of $3,000 or more per annum - non-farm work major source of income - owner less than 60 years of age)

- Non-farmers II (Non-farm income of less than $3,000 per annum - non-farm work major source of income - owner less than 60 years of age)

- The elderly (Gross crop, livestock and woodlot income of less than $3,750 per annum - owner 60 years of age or over)

- Non-residents (Owners living outside the study area - Estates, government school and church properties)

The properties associated with each landowner group were then mapped in order to relate socio-economic characteristics of owners to land use and capability. An examination of this map indicated that three quarters of the gross farm income generated in the area was derived from properties concentrated in two clearly defined agricultural nodes. A considerable portion of the land used for agriculture, but having a high potential for waterfowl use, was found to generate little agricultural income. This suggests that some of these lands could be phased out of agriculture and developed as waterfowl habitat without seriously affecting the area's agricultural economy.

The analysis of the main characteristics of the various landowner groups also brought to light a number of other points. For example:

1. The majority of landowners in the area do not depend on land resources for their primary source of income. Income from non-resource-based activities accounted for nearly 82% of the estimated total net cash income earned by landowners from all sources, and only 79 of the 372 landowners interviewed were dependent on the sale of agricultural products for their major source of income.

2. The resource-based income of the area is derived from farming, forestry, and fishing, however, forestry and fishing account for less than 5% of the total gross income.

3. The commercial farmers account for 80% of all gross primary resource income, with an average gross income of $13,000 per annum. In marked contrast, the non-commercial farmers average a gross income from resource-based activities of less than $2,000.

4. The commercial farmers represent a minority of landowners (11%) but control about 50% of the improved acreage. The majority of landowners (82%) is represented by the non-farmers and the elderly. They control 40% of the improved acreage.

The physical inventory of the resources of the Tantramar marshes revealed the very good potential of the land for agricultural production. However, one of the main facts drawn from the socio-economic survey is that only a small segment of the population was actually dependent on land resources of the area for a living. This major disinterest in the land seems to have been associated with a general decline of small-scale agriculture in the Atlantic Provinces, a problem which is further aggravated by a property structure which tends to hinder any attempts to large-scale farming. In effect, fragmentation of land holdings presents a major obstacle to the promotion of more effective use of the land not only in the agricultural sector but in the forestry, recreational and wildlife aspects as well.

It was therefore recommended that any long-term development plan of the area should include the formation of a land development corporation in order to facilitate land acquisition and foster development through a land consolidation scheme.

The study also suggested that there is little justification for stimulating farm development outside the two major concentrations of commercial farmers. The indicative land-use plan prepared for the area reflects this view. It recommends that capital inputs from public agencies for agricultural development in the area be restricted to the two farm nodes. The plan also recommends that a positive program of protection and development of the important wildlife habitat of the area be given a high priority.

CONCLUSION

A brief examination of the land-use pattern along the shore of the Gaspé Peninsula, or the coastline of the Maritime Provinces, reveals cases of past and present misuse of the land. In large measure, these examples of poor land use reflect past perceptions and attitudes towards resource management. During the long history of land development in these areas, little concern was given to environmental issues.

In the Atlantic Region, the shorelines were occupied by people engaged in the fishery and farm-forest operations, and the settlement pattern took a linear form fronting the coast. Natural vegetation was largely removed along low sections of the coast suited for agriculture, and many of the tidal marshes that provided important wildlife habitats were dyked and drained for agricultural use. Over time, erosion and flooding problems emerged in many shoreland areas, and in some areas of relatively dense coastal development, the discharge of raw sewage into nearby streams and the adjacent coastal waters created water quality problems. The scenic quality of the coastal landscape has also been down-graded. Empty farmhouses, dilapidated docks and boathouses, and abandoned boats are scattered along the coasts; this phenomenon is a manifestation of the economic hardships facing small scale resource-based enterprises in the region. The relatively recent upswing in outdoor recreation activity has also made its impact on the shorelands. Unplanned cottage colonies, campgrounds and trailer parks have become an intricate part of the shoreland landscape. Too frequently, these developments, rather than enhancing the authentic quality of the landscape, have brought new problems.

In recent years, the demand for lands within the coastal zone have shown a marked increase. A large part of this demand stems from the rising levels of participation in outdoor recreation activities. Both local people and non-residents, acquiring large acreages of shoreland for water-oriented recreation use. Many of the best recreation shorelands are now in private hands and concern is mounting over the maintenance of an adequate supply of shoreland for public recreation use. Demand for lands along the shore by the industrial sector has also increased. This has led to a concern over possible land-use conflicts and environmental degradation.

The legacy of land use and management problems left by past development, the emerging problems associated with the new demands for shorelands and the public's concern for environmental issues, suggest that governments will have to introduce more rigorous land-use planning and control measures in the coastal zone if major land-use conflicts and serious environmental degradation are to be avoided.

The data base and methodology required to prepare land-use plans for shorelands in the settled portions of the country are largely available, although some gaps do exist; for example, information on the environmental

impact of certain man-using activities. Planned implementation presents a more serious problem. Although the institutions and legislation enabling the use of implementation instruments (e.g. zoning, building codes, subdivision regulations), are in place in all provinces, considerable controversy surrounds their application in a rigorous manner, particularly in rural areas. It would appear that a much greater effort must be placed on public education to create an awareness of land-use problems that are emerging and of the benefits to be gained through the preparation and implementation of land-use plans and controls in rural areas. If this challenge can be met, it should be possible to implement plans which will prevent misuse of the land, minimize land-use conflicts, and improve environmental quality.

Although these notes provide only a superficial coverage of some of the dimensions that must be considered in preparing and implementing land-use plans, it is hoped that they will engender an awareness of some of the issues surrounding land use in the coastal zone.

AN APPRAISAL OF THE PHYSICAL SUPPLY OF RECREATIONAL LANDS IN THE MARITIME COASTAL ZONE

D. B. Coombs[1]

The concern for the provision of public access to coastal areas for recreational purposes and the need for an understanding of the extent of the physical supply of the resources available to meet such demands is very current in land use planning considerations at provincial and federal levels. Increased mobility, leisure time and improved recreational facilities and equipment have provided the stimulus for a rise in participation rates in outdoor recreational activities which has maintained a growth rate in recent years of 7 to 10% per year. At the forefront of such activities is the ever increasing demand for opportunities for a coastal or seashore holiday which in turn is reflected in the steady rise in the number of out-of-province visitors to the Maritimes' coastal National and Provincial parks as well as to commercial and private seashore recreational developments.

All levels of government faced with the problems of management of coastal lands and the mounting pressures for public access to water-oriented recreational opportunities are very cognizant of the need for appropriate measures to be taken in protecting private and public interests through planning for the wise use of coastal resources.

In his recent paper on "Shoreline and Other Recreation Resources of Nationwide Concern" Mr. Lloyd Brooks notes that the management of shorelines so as to include recreation as a significant use factor presents a two-fold problem. The first is how to get substantial segments of quality shoreline back into public ownership and the second how to retain presently uncommitted or undeveloped shorelines for public use without undue restrictions on resource utilization and development for other than recreational purposes.

The significant question that arises out of such concerns is the matter of how much coastline should be allocated for outdoor recreational use and how much of this should be held in public ownership. In order to be able to answer this question, an overall study of the anticipated demands on coastal recreational resources is required as well as a knowledge of the extent and nature of the supply of the physical resource base.

In his study of "Tourism and Recreation in Relation to the Water Resources of the Maritime Provinces", Mr. William Baker points to the growing reliance of many communities in the Maritimes on coastal recreational facilities outside their jurisdictions to meet the demand of their citizens and out-of-province visitors for water-oriented recreational opportunities. Alienation of local and other coastal resources by pollution, industrialization and private development is creating the need to seek alternative opportunities thereby increasing the pressures on remaining coastal areas that still have the capability for a quality recreational experience.

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Ten or more years ago the Americans were quoting 10% of accessible coastline as being a desirable standard for public ownership. Today we hear the figure of 20% and up which is indicative of the increasing public pressure on coastal recreational lands and the growing demands being placed on these resources in fulfillment of leisure time needs. In Canada where similar pressures are mounting no apparent attempt has been made to develop such a standard possibly because we have not as yet perfected methods for analysis of outdoor recreation supply and demand factors which might encourage us to do so.

Through studies such as the Canadian Outdoor Recreation Demand Study (CORD) and related studies on tourism and the travel industry now underway by provincial and federal agencies we are beginning to cope with the problems of understanding supply and demand factors in relation to planning for the extension of outdoor recreational facilities. Park use prediction models and other methodologies for allowing demand factors to be analyzed in a way useful to planners have already evolved from CORD activities. Refinement is necessary however before these can serve as the basis for attempting to set arbitrary standards for reservation of coastline areas towards meeting future demands for public access and recreation opportunities.

The only recourse at the present time in considering the potential demand for coastal lands for recreational use is to work from basic principles and experience for the systematic reservation of strategic shorelines. An essential element is an inventory of shorelines including an appraisal of their resources. In the case of the Maritimes the classification of all lands for outdoor recreation capability, including shorelands, has been completed under the Canada Land Inventory program. This information which provides a measure of the supply of the resource base is now available for land use planning considerations or studies of the coastal zone.

The land use capability classification for outdoor recreation was developed as a national system for indicating comparative levels of recreation capability of non-urban lands. It identifies the type of recreation to which land is best suited as well as lands or features possessing outstanding or unique recreational values.

For those not familiar with the classification, it is based on the lands natural capability to provide recreational opportunities. The degree of attractiveness, the range of recreational activities possible under natural conditions and the number of people which can be accommodated on a total annual day use basis without damaging the resource base are dominant factors.

As in the other Canada Land Inventory classifications for land use capability, such as Forestry and Wildlife, Recreation uses a 7 class land unit rating scale with 1 as high. Class 1 units have a very high capability for outdoor recreational use while those at the other end of the scale, the 5, 6 and 7's have a moderately low to fairly low capability.

Use as applied to recreation lands and particularly to shoreline or coastal areas implies direct contact between the user and the feature being used whether it is simply a visual contact or a direct physical involvement. On this basis the inventory recognizes 25 recreation features representing the major recreational uses of lands. Specifically identified for water-oriented recreational activities are such features as shorelands with deep inshore water suitable for swimming or boat mooring, shorelands capable of supporting family bathing and beach activities as well as shorelands fronting

waters suitable for accommodating yachting or deep water boating. The recreational values of coastal or shoreland waters accrue to the adjacent land unit and may have an effect on the rating of the land unit for recreational capability.

The foregoing represents a very brief sketch of the kind of information available from the Recreation Land Use Capability inventory now completed for the Maritime Provinces. Essentially, it provides a basis for assessing the nature of the physical supply of coastal recreation resources against those of competing resource use and implications of social and economic factors when examining options for the management of coastal lands.

Turning to a look at the physical supply of the Maritimes' coastal recreation resources, as provided by the C.L.I. Recreation information, there are some 3,962 miles of ocean shoreline involved. Based on a somewhat cursory examination of the linear distribution by class the coastal shoreline capability for recreational use in the three provinces is indicated as follows:

(a) Prince Edward Island - 688 miles.

Class 1, 20%; Class 2, 15%; Class 3, 23%; Class 4, 18%, and the balance of 24% represents Class 5 to 7 or lands in general not suitable for fostering intensive water-oriented recreational activities.

(b) Nova Scotia - 2,517 miles.

Class 1, 1%; Class 2, 4%; Class 3, 10%; and Class 4, 22%, and the balance of 63% as Class 5 to 7.

(c) New Brunswick - 947 miles.

Class 1, 1%; Class 2, 5%; Class 3, 24%; Class 4, 25%, and Class 5 to 7, 45%.

The overall picture for the Maritimes is Class 1, 4%; Class 2, 6%; Class 3, 18%; Class 4, 22%, and Class 5 to 7, 50%. In the Class 1 to 3 coastal lands of moderately high to very high recreation capability and representing 28% of the total coastal zone, or approximately 1,100 miles, the principal recreational land use opportunities are identified as family bathing and beach activities, family and other recreational lodging use as well as various degrees of boating, fishing and other day-use activities such as viewing, hiking gathering, etc.

In terms of recreational day-use activities, based on beach-use standards of two feet of beach front per person with a turn over rate of two persons per day, the total capabilities of the 1,100 miles would suggest a staggering 5,808,000 recreational day-use potential per day. When one considers the total annual visitors to Prince Edward Island National Park is in the order of 2,093,992 a year, which is essentially a totalling of day-use visits to the park, one can gain some sense of scale for the potential of the Maritimes' coastal zone for water-oriented recreational use.

As already mentioned the availability of coastal lands for recreational use is affected by problems of pollution, industrialization, private ownership and lack of public access. In Prince Edward Island some 95% of the shoreland is in private ownership and the picture is somewhat similar in

the other two provinces. Only a comprehensive study of the coastal zone resources in terms of supply and demands for all potential uses will permit a realistic appraisal to be made of the potential of the Maritimes' coastal areas for appropriate development of recreational use. The C.L.I. Land Capability for Recreation inventory data will provide a very useful base for developing a picture of supply for coastal management and planning consideration for this purpose.

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COASTAL GEOMORPHOLOGY AND MAN

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INTRODUCTION

Throughout history man has occupied the coastal environment which serves as a haven for his water-borne transport and as a spring-board for his advances into the continental interiors. His tenure of this highly dynamic interface between land and sea has been constantly attended by the relentless energy of the sea and its capability to modify and reshape the land. In his attempts to ameliorate the destructive forces of the sea and to modify the environment to meet his needs he has, through his construction of shore and inland installations and his relocation of sediment, placed himself in the role of an active geomorphic agent. All too often, however, his execution of this role has been in ignorance of or without regard to the manifold factors that constitute the energy balance between sea and land.

In the following paragraphs a modest attempt is made to provide a perspective of the geomorphic aspects of Canadian coasts and their significance to man.

COASTAL TYPES

Canadian coasts are characteristically extremely youthful, having been relatively recently rejuvenated by intense glacial scour that accentuated every detail of bedrock structural fabric and lithologic difference. Moreover, large areas are still being renewed in a very real but different sense. Most of the Atlantic Provinces for example, are presently submerging because of crustal subsidence. There, the inherently tortuous shoreline is being forced to migrate even faster landward into subaerially dissected terrain. On the other hand, larger areas (including Hudson Bay, the eastern Arctic, and Labrador) are still emerging because of postglacial isostatic uplift, that effectively defeats the normal erosional transgressive tendency of coasts by shifting the shoreline seaward onto more mature surfaces of deposition.

The thousands of miles of Canadian marine coastline and fresh water shoreline that extend throughout a wide variety of geological and climatic settings present a formidable challenge for a classification enthusiast. Any attempt at a detailed classification of Canadian coasts is far beyond the scope of this paper. However, it is evident that coastal characteristics are determined by terrestrial, marine and atmospheric factors that have interacted continuously within the framework of time. These factors are summarized in Table I.

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[1]Geological Survey of Canada, Department of Energy, Mines and Resources.

TABLE I. FACTORS AFFECTING COASTAL CHARACTERISTICS

TERRESTRIAL	MARINE	ATMOSPHERIC
TOPOGRAPHY	TIDAL RANGE	CLIMATIC
Coastal Plan	CURRENTS	Precipitation
Coastal Profile		Magnitude
Orientation	Direction	Duration
	Magnitude	
		Temperature
GEOLOGY	FETCH	Magnitude
		Duration
Lithology	EXCEPTIONAL EVENTS	(ice)
Coherent coarse sediment	Tsunami	Wind
Noncoherent fine sediment	Seiche	Velocity
	Cumulative forces	Duration
		Direction
Stratigraphy		
Structure		
HYDROLOGY		
Sediment load		
HYDROGEOLOGY		
VEGETATION		
	TIME	
Geological History	Isostasy Eustasy	Influence of Man

Even the most cursory examination of our coastlines would reveal that marked variations in the controlling factors can occur, often within very short distances, along any coastline. These variations may be attributable to such conditions as:

1. Alteration of more or less resistant strata in a folded succession as to variations in the intensity of jointing in crystalline rocks.

2. Undulation above and below the shore of a contact between coherent bedrock and superjacent incoherent Quaternary sediments.

3. A concentration in supply of terrigenous sediments at specific sites along the coast, as for example, at the mouths of streams.

4. Variations in degree of exposure along an irregular coast developed by glaciation and not yet adjusted to shoreline processes.

In both regions of marine and fresh water, Canadian coastlines are of two main types namely: Prograding Coasts and Retrograding Coasts.

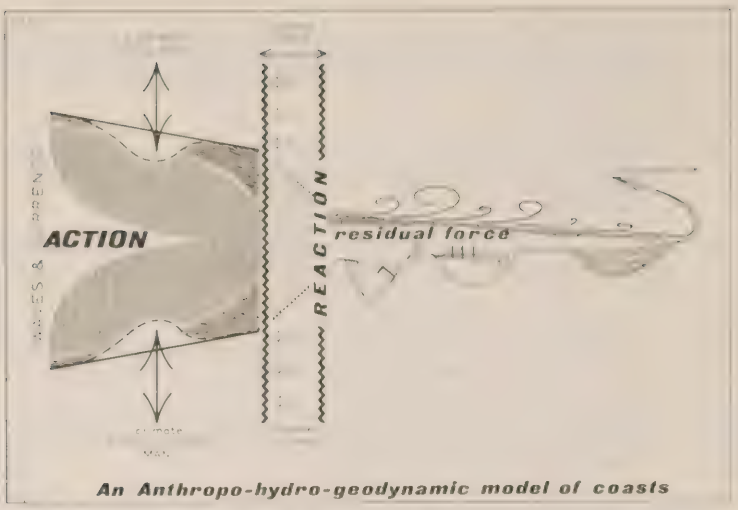
Prograding coasts are those that are developing in a seaward direction notably along delta fronts or in sheltered bays that are depositories for the erosion products of adjacent headlands. Because of the low, flat land developed by progradation, these coastal segments are commonly more highly developed by man than any nearby retrograding coast. Inherently, however, these prograding coasts are also commonly highly sensitive to man's activity. Many of the arctic coasts are in this category as a result of intensive frost action on bare slopes which produces an abundant supply of detritus to shores protected from intensive wave action by widespread sea-ice.

Retrograding coasts, in comparison, develop through encroachment of the sea upon the land. The rate and extent of development as well as the physical characteristics of retrograding coasts is controlled, in large measure, by the characteristics of the shore-forming materials. In regions of hard, competent, crystalline rock either high or low coasts may develop. In Canada, high coasts of this type are to be found along the glacier-carved fiorded coasts of British Columbia, Labrador and eastern Baffin Island. Good examples of low coasts developed on hard rock may be found in many parts of Nova Scotia.

Short segments of both high and low coasts may be mantled by unconsolidated sediments. Where exposed to open water these segments may be subject to accelerated erosion or, where sheltered, to local progradation such as at the mouths of sediment-rich rivers.

Wherever weak, incoherent sedimentary rocks are exposed to open water, coastlines tend to be retrograding and characterized by fine-grained beaches such as those of Prince Edward Island and eastern New Brunswick. Coastal zones composed of unconsolidated sediments tend to be subject to even greater erosion.

If boulders and cobbles are prevalent in the sediments, these materials tend to form protective beaches except on very exposed sites. Sand and finer



An Anthropo-hydro-geodynamic model of coasts
Figure 1

grained sediments, however, offer little or no protection against wave action even in relatively sheltered sites. Where ground ice is present within such sediments, as in the coastal cliffs of the western Arctic, retreat may be still more rapid because of melting on exposed surfaces.

COASTAL PROCESSES

Although an understanding of the various static factors that influence coastal development is important, any consideration of coastal geomorphology must include an examination of the dynamic processes that are unique to this environment.

Coastal processes result from the essentially unidirectional flow of energy from two very dynamic agents, the sea and the wind, across the shoreline discontinuity where the energy is absorbed as work done on the relatively passive land surface (Figure 1). The system is one of action and reaction whereby the land suffers modification by erosion that tends to straighten the shoreline. Man through his structures may defy and temporarily defeat this tendency. In so doing, however, he may disrupt finely adjusted interactions and thereby cause deleterious effects. Much of the evidence of man's adaptation to the coastal environment is, unfortunately, a sad testimonial to his poor understanding of the processes.

In general, the system can be viewed as overwhelmingly in favour of the sea because the net effect is to drive the shoreline landward into man's domain, notwithstanding such short-term progradational features as pits, barriers and deltas. Exploitation of these deposits for their materials can commonly expedite a return to the natural condition of erosion. The general transgressive tendency can be greatly augmented by submergence, resulting from tectonic subsidence or eustatic sea-level rise or it can be defeated more or less completely by coastal emergence.

A continual flow of energy impinges on the coast as waves, currents and wind which act in concert to disaggregate and redistribute the earth materials opposing the impact. Tides provide additional energy and increase erosional efficiency by generating locally important currents and by extending the vertical range over which the waves and currents can work. In the Arctic and Great Lakes, drift ice and shorefast ice dampen or cancel wave action for considerable periods each year, but it can more than compensate for its protective effect when acting as a battering ram and rafting agent during break-up. In general, however, the major modulations of the energy flux are due to short-term weather and storm surges, by seasonal tidal changes, and by long-term climatic changes.

At the coast most of the energy is consumed doing work by erosion and by the redistribution of sediments, thereby modifying the shoreline configuration. Like subaerial denudation, the net tendency of all coastal processes is to planate the surface of action, to reduce it to baselevel by removing the projections and filling the hollows and to produce a smooth interface and a straight shoreline. However, since perfect linearity is a theoretical abstraction, and since shoreline regression can never keep pace with changes in baselevel, the coast is continually adjusting to maintain a steady-state condition of metastable equilibrium. In maintaining such a condition the system is infinitely responsive to the multitude of short-term and local changes in each variable. The sediment load, in transit from source to sink and manifest as depositional forms, acts as a very sensitive buffer to absorb the energy and reaction imbalances created by changing regimes. Hence shoreline features, such as spits, barriers, deltas and forelands are characteristically changeable and ephemeral. Yet here, because of the intrinsic aesthetic appeal and conducive physical characteristics of these features, man is to be found in greatest numbers, modifying and exploiting these sensitive and delicate substrates to his own use and commonly, misuse.

At the shore, erosional processes act on earth materials varying in resistance from solid unjointed bedrock to cohesionless, unconsolidated sediments. Suites of shoreline processes vary regionally as a result of the gross shoreline configuration that, in any extremely youthful state, is inherited largely from the glacial rejuvenation of structural and lithologic differences. Coastal configurations will thus range from drumline - tombolo complexes, to linear cliffs in subhorizontal layered rocks, to crenulate jagged igneous terranes, to tortuous fingers in folded terranes. Youthfulness thus imparts a distinct impetus to the forces of change, analogous to the greater potential for denudational processes provided by relief and evaluation.

In the surf zone most of the energy available for coastal processes is consumed on impact by friction and self-destructive turbulence, and by the disaggregation of earth materials and the reduction of particle size by attrition.

Because wave energy is focussed by refraction onto headlands, an energy gradient is established which diminishes laterally toward adjacent embayments. Also, after a wave destruction on the beach a small residual force vector remains that is directed down the energy gradient. This vector, coupled with that resulting from imperfect refraction because of abrupt shoaling and forced waves, established a head of water which in motion is manifest as a longshore current. By this means, sediment is transported from

headland source to settling basin, down a similar bayward slope of the longshore profile. Additional sediment is moved by littoral drifting, a process by which beach-face particles follow a zig-zag path along the beach because of oblique wave incidence. Reference to beaches as "rivers of sand" alludes to these gradients down which a stream of water flows along the coast carrying fine sediment in suspension and coarser sediment in traction.

Kinetic energy of a current is lost in transit to a depositional site by laminar shear, by eddy diffusion with offshore water, by friction with the bottom and its bedforms, and by grain-to-grain impact of saltating particles. The waning transporting power promotes deposition in any irregularity. Bayhead beaches are prograded, and spits are extended to become barriers across inlets.

Ultimately, opposed longshore currents meet at bayheads and are deflected seaward as a plume-like rip current or as sheet underflow. By these means, excess sediment is moved offshore to aggrade the profile of equilibrium until eventually the bay is either filled or a barrier emerges across the opening.

Coastal processes are markedly weather-modulated on daily, seasonal, and secular time spans because variations in sea state, wave spectrum, wind, tides and storm paths determine wave and current regimes. As a result, striking variations in the type, rate and direction of shoreline change occur that, when viewed from the human point of view, often seem sudden and spasmodic and are often regarded as unrelated, unpredictable acts of God rather than as symptoms of a natural continuum. Analysis of coastal behavioural trends should therefore include the study of changes averaged over several decades in order not to be misled by spurious short-term effects. The use of sequential aerial photographs of a variety of coastal terrains can aid in these studies.

MAN'S EFFECT ON COASTS

The effects of a man-made perturbations on the system are difficult to predict or even to recognize because of the complex interaction of process elements and because sudden natural changes may be misconstrued as man's fault. Any appreciation of man's impact, however, must begin with a knowledge of the components, and be supported by case histories. In general, man's effect is to lessen the resistance of the coasts weak defenses, thereby accelerating the rate of change, as well as to induce change on formerly static areas. While man may locally arm the shore with a protective structure to stem erosion, often shoreline retreat can be only temporarily forestalled.

Specifically, man's intervention in coastal processes is usually either to interrupt longshore drift or to modify shoreline geometry. Construction of seawalls, groins and the exploitation of beach materials all have immediate, but sometimes subtle effects on shoreline retreat. Longshore drift is temporarily decreased, causing oversteeping and erosion of the beach profile in the immediate vicinity of the structure and a somewhat later regression of the shoreline down beach along spits and barriers. Removal of beach sediment creates a local sink and an oversteeping of the longshore gradient which is adjusted back to equilibrium by upbeach propagation of the deficiency back to the headland source where erosion is accelerated.

Dredging of inter-barrier inlets interrupts drift continuity, changes the beach sediment budget both up and down shore, and intensifies erosion by changing channel geometry.

Large structures such as tidal dams and causeways may gravely affect tidal regimes, change wave and current patterns, and impede drift ice; usually leading to intensified erosion. Dyking of extensive areas around the Bay of Fundy (ca 100,000 A) has removed a large and most efficient sediment trap - the intertidal salt marsh - which formerly extracted vast quantities of suspended sediment. Furthermore, the practice creates a commitment to maintain dyke integrity as the reclaimed land sinks lower relative to sea level and the flood threat increases.

Loss of cliff-side buildings, highways and property through coastal erosion, common in the Maritimes and elsewhere throughout Canada's coastal environment, constitutes both a significant hazard to life and an economic loss. The severity of the hazard and the magnitude of economic loss reach maximum proportions in highly populated urban areas where shore land uses such as recreation, transportation, marine commerce, industrial and residential development tend to be intense and the value of shorelands tends to be high.

In less intensively developed areas shore protection measures may be economically unfeasible, however, the risk of hazard and property loss can be minimized through sound land-use planning based on a knowledge of rates of retreat. Sound land-use planning is also essential in more intensely developed coastal regions but here it also becomes necessary and economically feasible for man to study and, to a certain extent, modify or control the geomorphic processes operating in the coastal zone.

A good Canadian example of erosion control and beach stabilization practice and development in a highly developed urban environment is provided by works in progress along the Toronto waterfront.

The Toronto waterfront area is naturally active. The coastal materials consist almost entirely of unconsolidated sand, silts and clays. Where bedrock is exposed, it consists of erodable shale. The Scarborough bluffs, ranging in height up to 100 M, extend for 16 km east of Toronto. These bluffs are receding at an average annual rate of .4 to .5 m/year and are contributing each year approximately 300,000 m^3 of material to the lakeshore. Approximately 19,000 m^3 of this amount is of sand size or larger and may be transported westerly in the littoral drift (Fricbergs, 1970). The Upper Bluff strata are susceptible to gully erosion and this, combined with progressive shoreline recession, constitutes a real hazard for housing developments now crowding toward the lakeshore.

The shoreline fronting Toronto and west of Scarborough Bluffs is markedly embayed. A recurved spit complex (Toronto Islands) has developed across the eastern part of this embayment to form Toronto Harbour. Two entrances to the harbour are maintained by the Toronto Harbour Commissioners. The eastern channel, through the 'neck' of the spit complex traps sediment moving westerly with the littoral transport from Scarborough bluffs and, until recently, had to be dredged regularly.

Two rivers contribute predominantly fine-grained sediment to the Toronto waterfront system. The Don River empties into the protected harbour

waters and its sediments are removed to deep water by dredging. Further west, Humber River sediments are carried into the general lake embayment beyond the Toronto Island spit complex.

Wind, waves and wind-induced currents are the principal sources of energy by which sediment is transported and shorelines are modified in Lake Ontario. At Toronto the largest waves, which contribute most energy, attack the shore from the east primarily during the winter months; lesser waves commonly originating in the southwest, are also important.

The demand for greater harbour facilities has led the harbour commissioners to undertake several successful landfill projects. Fricbergs (1965, 1970) has engineered a system whereby the lakeward margins of freshly-filled areas are developed into stable beaches using clear inorganic fill from construction, excavation, or demolition projects in the nearby city area. In general, the following four principles are applied after the designer is in possession of full wave, climate and bathymetric information.

1. The beach to be stabilized must be supported at each end by an anchored headland, groyne, jetty or breakwater etc.

2. Since the beach slope depends on particle size, steep stable slopes are best (and most cheaply) achieved by nourishment with coarse particles from fill material.

3. The beach should be oriented normal to net wave approach.

4. The average beach line between supports should describe an arc of about 15 degrees.

The east headland is a good example of a landfill and erosion control project. It is part of a plan to construct an outer harbour on the gently sloping shelf offshore from the present Toronto Islands.

This narrow promontory was started in 1965 and by 1970 it projected over 3 km southwest into the lake along the 9 - 10 m bathymetric contour line. Each winter storm season has widened or recurved its end and left an annual growth ring. The lateral movement of material has necessitated the construction of interceptory promontories at right angles to the headland. The width of the headland diminished on the average 12 m, 6 m, and 3 m with each of the first three winter seasons. After several years the exposed slopes have been modified into stable beaches. Stability is enhanced where the beaches were nourished with pebble to boulder-sized pieces of brick, paving stone, asphalt and broken concrete.

Stable beaches have been built embodying the above principles, to protect Ontario Place from the open waves of Lake Ontario. This recreation and exhibition complex is built on landfill placed outside the breakwater in Humber Bay, Toronto.

CONCLUSION

It can be anticipated that man's activity in the Canadian coastal environment whether for industrialization, transportation, recreation or resource development will be intensified in the years ahead. Although the

location, level and purpose of these activities may be presently uncertain, there can be no uncertainty that these activities will be confronted with the same dynamic geomorphic processes and the reaction of the land to them that have prevailed throughout geological time.

Coastal geomorphic studies on both a regional basis, as a part of terrain inventory, and on a more detailed scale to evaluate coastal performance and to assist in the evaluation of the impact of man's development of the coastal regions, thus constitute a significant component in an interdisciplinary approach to an understanding and beneficial use of the Canadian environment.

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OWNERSHIP OF AND ACCESS TO COASTAL LANDS:

SOME PRACTICAL IMPLICATIONS

D.K. Redpath[1]

INTRODUCTION

> The shore is the gateway to the water; the use and enjoyment of water largely depends on access via the shore. Shore differs from other land because it belongs to water as well as to the land itself. It is subject to all controls of land use, plus some additional safeguards which its exceptional function demands. We are in a period when the whole concept of shore line use and preservation is being moulded to meet new demands. In today's explosion onto the water, the shore is no longer merely an edge; it has become a spine, the nerve centre of public recreation.[2]

That statement captures the importance of the shore and the essence of the demands being exerted on this contact zone between land and water. Even more enlightening is the fact that it appeared in one of the Background Papers prepared for the Resources for Tomorrow Conference which was held over a decade ago; only now are we becoming increasingly concerned with some of the issues raised at that time.

Why has there been this renewed interest in the shore? It has undoubtedly been due, in large part, to an awakened public interest in environmental issues and an increasing public awareness that the land and resources in this country, especially coastal land, are not unlimited in supply. Non-resident ownership of water-front lands, rapid growth of private cottage development and the increasing difficulties experienced by the public in obtaining easy access to the shore have become important issues in several areas of Canada. Although the physical resources and demands for recreation vary widely within this country, perhaps nowhere have these issues become more clearly focused than in the Maritime Provinces.

Earlier this month, along with three or four others in attendance at this conference, I had the opportunity to participate in a seminar on the use, ownership, access and management of shoreland in the Maritime Provinces. That seminar, which was sponsored by the Lands Directorate, brought together some thirty individuals concerned with the problems, both as administrators

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[1]Lands Directorate, Lands, Forests and Wildlife Service, Ottawa

[2]Norah Johnson and Joyce Tyrrell, "Problems and Techniques of Land Acquisition", Resources for Tomorrow Conference Background Papers, Vol. 11 (Ottawa, 1961), p. 1017.

and researchers. The majority were federal and provincial officials, but there were also a number of university researchers who have been concerned with the problems, as well as a representative from the State of Maine in attendance. Although the long-term results of this seminar remain to be seen, a number of interesting points were raised during the deliberations. Some of these considerations will be presented in this paper, in addition to the results of empirical studies conducted on ownership and access in the Maritime Provinces over the past five years.

This paper discusses, from a recreational-use point of view, the importance of two components in programs aimed at the wise use and management of the shore zone: ownership of coastal lands as an essential part of the information base and access to coastal lands as one of the very basic requirements for meeting the recreational needs of the public.

OWNERSHIP

Information regarding land ownership is vital in any program aimed at the efficient management of resources, including the land resource used for recreation. One of the first considerations in any discussion of coastal land ownership is to clarify the situation seeking answers to such questions as: Who owns the coastal land? How far do riparian owners' rights extend? What rights do the public have on privately owned land? A lengthy discourse on the legalities of land ownership is beyond the scope of this paper; it will be sufficient merely to mention that the legal aspects of coastal land ownership are far from being clearly established. For example, in many parts of the Maritime Provinces the problem is one of unclear property titles, and with coastal land there is the added complication that the original property deeds do not clearly define the shore boundary of the property.

Ownership and control of land may be either in public or private hands and within each type of ownership there are a variety of activities for which the land may be used. Public limitations, such as development control, may be used to limit the activities that an owner or occupant of the land may pursue. With respect to land used for recreational purposes, for each type of ownership the land may be open for public use (in some instances for a fee, such as a campground) or available to only restricted groups.

Information on coastal land ownership should be regarded as an important component of the information base needed for the implementation of an effective coastal zone management program. Anyone who has been involved in land management programs in the Maritime Provinces will be familiar with the problems and frustrations encountered in trying to obtain, or even assemble, information on land ownership. In many areas of this region the only available maps indicating property ownership are the original land grant sheets which are over a century old. This results in some serious consequences. For example, the issue of non-resident ownership could have been supported by factual data rather than emotional concern, had up-to-date property ownership maps been available. The absence of such maps is also important with respect to the practice of fair property tax assessments; the lack of adequate, up-to-date property ownership maps prevents an undetermined number of properties from even appearing on the assessment rolls.

In order to tackle the problem described, the Atlantic Development Board launched a program in the late 1960's enabling federal funds to be expended on a regional program of surveying, mapping, titling and land registration. In February, 1972, it was announced that the three Maritime Provinces had agreed to co-operate further in this area with the decision to form a single survey and mapping agency for the three provinces.

During the period 1965-69, property ownership mapping was carried out over several widely scattered regions of the Maritimes by a small group that was, at that time, within the Department of Energy, Mines and Resources. The property maps compiled are not a legal description of the properties, but they do provide some very good examples of the complex ownership pattern that is characteristic of the Maritime Provinces (Figure 1).

A series of these maps covering a major portion of Bras d'Or Lake in Cape Breton Island was completed in 1967. In addition to plotting property boundaries of those owning more than five acres around the Lake, this work also listed the property owners with respect to place of residence. During 1971 a group from the Institute of Public Affairs at Dalhousie University, using this previous work as a reference point, updated the 1967 material and added information on land price changes and changes in assessed values of the properties over a ten year period.[3]

This latter study revealed that 16 per cent of the properties fronting on the Lake were owned by out-of-province residents (as compared to 12 per cent in 1967) and 11 per cent of these were residents of the United States. The study also reveals that one of the consequences of the purchase of property by absentee owners is the effect it has on the permanent residents of the area.

The search for rural properties for use as seasonal residences, especially those with shore frontage, has meant a dramatic increase in the value of this land compared to its value for use in agriculture or forestry. Since legislation requires properties in Nova Scotia to be assessed at actual cash value, these property purchases by seasonal residents result in higher property assessments. Although the assessed value of properties tends to lag behind the actual cash value at any given time, it is certain that the higher assessments and taxes cannot be met by many of the permanent residents engaged in marginal farming, fishing or woodlot operations. The pressure of higher assessment and consequently higher taxes may force the residents to either sell to a non-resident, who can afford to maintain the property and pay the taxes, or to subdivide the property for cottage lots. Most of us are familiar with what has happened in the past when a property has been subdivided for cottage lots: either a string of cottages along the shore or an uninspiring, simple grid subdivision with little or no consideration being given to the natural features of the landscape in its design.

A study conducted by the author[4] in 1970 along a 120-mile stretch of Northumberland Strait from Shediac, New Brunswick to River Philip, Nova Scotia (Figure 2), revealed that three-quarters of the cottages along this stretch of shoreland were located on lots of less than 20,000 square feet in size and some were even located on lots as small as 2,500 square feet.

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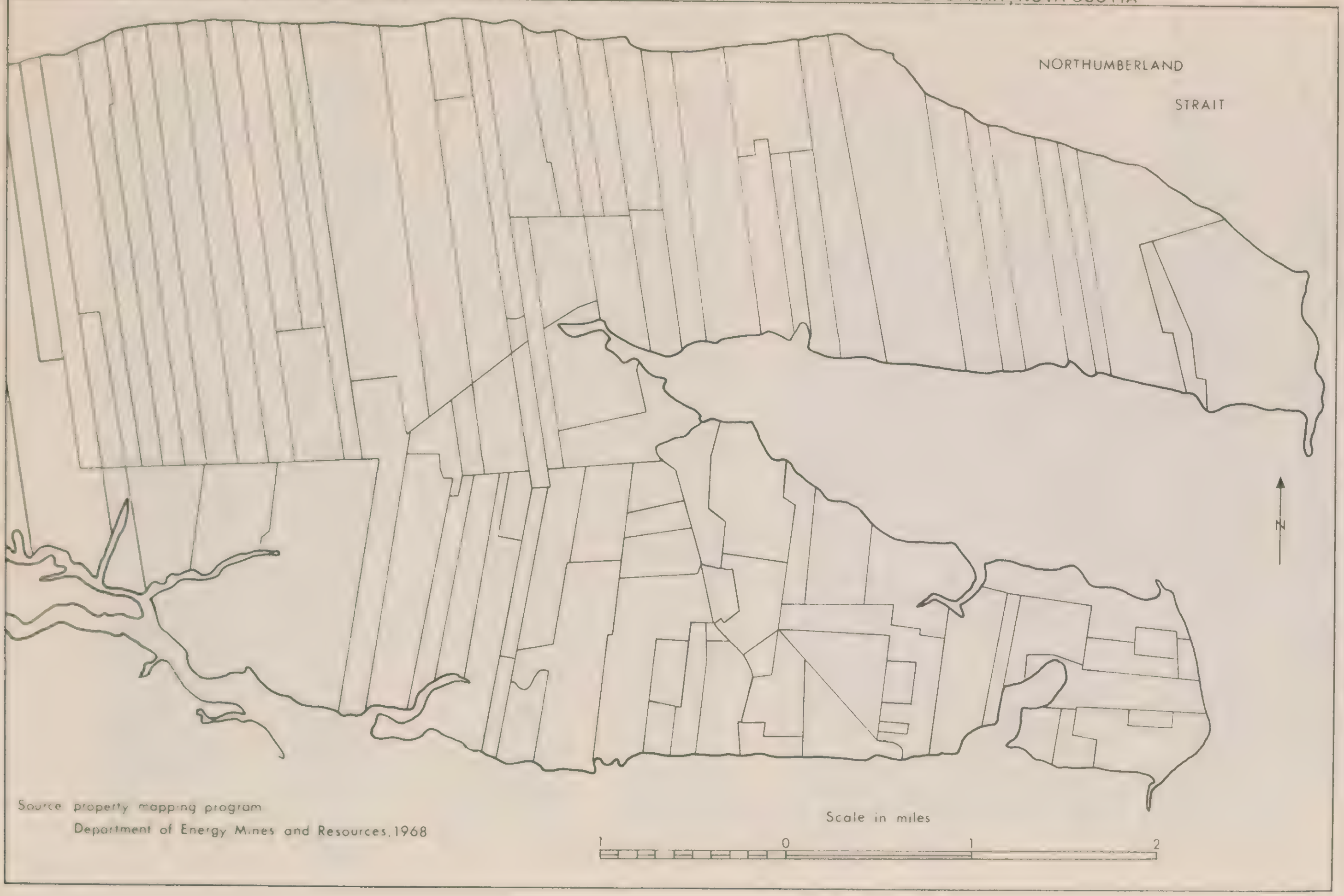
[3]Kell Antoft, et al., Matters Related to Non-Resident Land Ownership in Nova Scotia, Discussion Paper (Halifax: Institute of Public Affairs, Dalhousie University, 1971).

[4]D.K. Redpath, "Policy Implications for Shoreland Recreation: A Pilot Study in New Brunswick and Nova Scotia", (Unpublished M.A. thesis, University of Waterloo, 1971).

FIGURE 1. AN EXAMPLE OF THE LAND OWNERSHIP PATTERN NORTHUMBERLAND STRAIT, NOVA SCOTIA



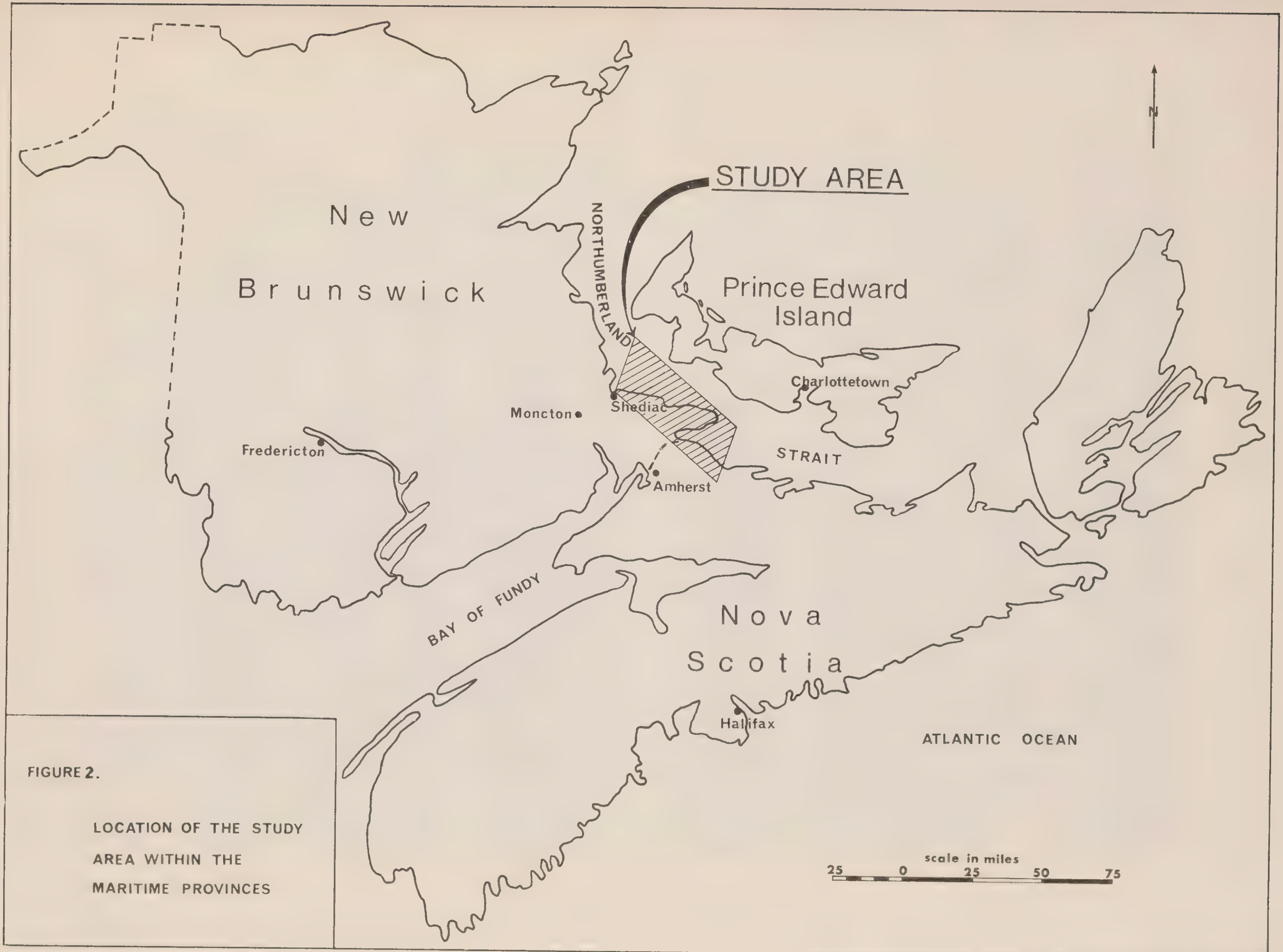


FIGURE 2.

LOCATION OF THE STUDY AREA WITHIN THE MARITIME PROVINCES

In addition, many of the lots had not been surveyed. As a result, various geometrically shaped lots and incidences of the same lot being sold twice are not uncommon in this area. With virtually all of these cottagers utilizing septic tanks for sewage disposal and individual wells for their domestic water supply, it is obvious that over a period of time the result will be a severe pollution problem, especially where there is a congested cottage colony.

An example of the seriousness of the pollution problem which can develop in a congested cottage colony is illustrated by a situation which developed at Shediac, New Brunswick. In 1968 a crisis situation existed in the area: not only was the use of one of the finest quality beaches in eastern Canada threatened with closure due to pollution from domestic sewage, but the groundwater in the area immediately adjacent to the beach was polluted as well. The approximately 750 cottagers in this area were advised by the District Medical Health Officer to boil their water before using it. A consultant's report recommended an estimated expenditure of $1,050,000 (based on 1968 figures) for collection and treatment facilities to alleviate the problem. By 1970, this estimate had risen to $1,740,000 at an annual cost per residence of $40-$75.[5]

Another interesting issue with respect to the problem in this specific area is related to the ownership and tenure of land. Since virtually all of the land in this shore area is leased by cottagers from two major land owners, it raises the interesting question as to who pays for the costs of major improvement works - the owners or lessees.

ACCESS[6]

Similar to the discussion on the ownership of coastal lands, there are some important questions related to access to the shore which must be answered: how, in what locations and by what means can access to the shore be preserved for the general public? Surely access to the shore is not only for those who own shore-front property, but should also be ensured for the general public who cannot afford or do not want to own property, but merely "seek a spot for the day" at the beach.

Outright ownership of land is, of course, the most certain means of ensuring access to a particular shore area. Public agencies which purchase land include various federal and provincial government departments as well as municipal governments. Certain regional authorities such as the Conservation Authorities in Ontario may also be empowered to acquire land. There are also specially created agencies, such as the Land Development Corporation in Prince Edward Island, which act as a purchasing agent for land on behalf of the provincial government.

Trusts, associations and co-operatives are among private agencies which are active in land purchase. In some instances public and private agencies may work together to acquire land. For instance, in the State of Maine, the Nature Conservancy acquires property and then turns it over to a government agency or department to maintain and manage.

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[5]Moncton Transcript, July 15, 1970

[6]Access as used here, refers exclusively to access for purposes of recreational use.

The other basic element in land acquisition, aside from the method and agency responsible for acquisition, is that of funding. Numerous government departments, both federal and provincial, have funds available for land acquisition. In addition, there are shared-cost programs, such as the ARDA agreements, which also provide funds for acquiring land.

Techniques which might be employed when land is being considered for acquisition by a public agency are: a revolving fund to provide an agency with an initial sum of money for land purchase and a replenishment of the funds as regular appropriations are made; pre-emptive buying - purchasing key pieces of property; purchase and lease-back; and purchase and sale-back. To my knowledge these techniques have not been widely employed in public land acquisition in Canada.

However, due to the prohibitive expense of purchasing all key shore areas deemed desirable and the availability of suitable coastal land, there are limitations to the effectiveness of outright acquisition as a means of guaranteeing access to the shore. Among other methods which may be used to accomplish this are: (1) transferring allocated land to recreational use. For example, land already owned by a public agency but used for some other purpose at present; (2) as a by-product of public undertakings. This involves the use of land acquired by a government agency which is excess for the purposes acquired; (3) expropriation; (4) purchasing rights in land (easements); (5) donations; (6) private philanthropic funds; (7) development control - subdivision by-laws, zoning by-laws, tax measures; (8) survey roads; (9) reservation - reserving a buffer zone around the shore or reserving blocks of land at key intervals along the shore.

Perhaps access to the shore can best be ensured not by any one of these approaches, but through their combined use depending on the particular situation.

It is not enough, however, to simply provide access by means of acquisition of a beach. Back-up land to provide for facilities such as carparks and change houses which the recreating public now expects, must be provided as well. Although it is important to have designated public access points to the shore, rather than absolute numbers, acreages, or mileages, the most important concern should be the provision of access at certain key locations. The key sites to be designated are not only those of high capability for recreational use, but also those near the large urban centres of a region.

Once again referring to the study conducted by the author along Northumberland Strait in 1970, 95 cottagers were interviewed to obtain information on this aspect of coastal land use. One of the questions posed was whether they felt there was a problem of access for the general public to the shore. Approximately one-third of the respondents replied in the affirmative. The revealing part of the responses was that approximately one-half of those in the Nova Scotia portion of the study area felt that there was an access problem. This response is probably explained by the fact that there were no publicly developed beaches in the Nova Scotia portion of the study area (although there were three Crown owned shore areas where access was possible and one of these had parking facilities); whereas, in the New Brunswick portion there were two provincial parks with facilities such as change houses at the beaches.

Although it is possible to question the method of asking a group who have access, by virtue of ownership or use of a cottage, whether there is a problem of access for the public to the shore, the results reflected what the author sensed the situation to be in the summer of 1970.

There is also the question: does the build-up of cottages along the shore restrict access? The results to this question, as revealed by interview responses, indicated that cottagers were affirmative in their replies, especially in Nova Scotia where 77 per cent stated they felt that the build-up of cottages restricts access to the shore. These results are supported by the fact that initially, cottage development along this stretch of coastline is characterized by a single row of cottages along the waterfront. If the demand pressures are great enough, a second or third tier of cottages may be built. This "ribbon" type of development not only effectively eliminates the opportunities for public access to the shore, but also creates an access problem from the second and third-tier cottages and lots.

It was also interesting to note that when talking to the cottagers, several indicated the build-up of cottages leaves the impression that most of the shoreland is private and that access may only be obtained by trespassing over a cottager's private property. This illustrates the importance of visual access for the public as well as physical access. For instance, how many of you, when driving along stretches of attractive coastline, such as portions of Northumberland Strait, are left with the impression that the shore is almost completely occupied by cottages or some other form of development?

Improved standards of design such as cottage site planning using cluster techniques which utilize the natural features of the landscape would be an important element in reducing the problems associated with uncontrolled cottage development. At the same time it would assist in preserving the natural character of the coastline and provide better access to the shore from a greater number of cottage lots.

In conjunction with improved cottage subdivision design there would appear to be wide scope for the application of the condominium approach which has been developed in urban areas. For instance, rather than individual ownership of shore-front property, the shore-front could be reserved as common land.

FUTURE CONSIDERATIONS

Hopefully, this brief discussion of some of the issues involved in the ownership of and access to coastal lands, has brought out some of the challenges which must be faced by those who are concerned with the proper planning and management of the coastal zone. Prior to closing I would like to leave the following points with you for consideration.

1. Ownership of coastal land. How much of the coastal land in Canada is in public ownership? Where the land is in public ownership, is access possible or permitted? In the United States for example, it has been estimated that only three per cent of the approximately 100,000 miles of U.S. shoreline is publicly owned and available for recreation. What is the corresponding figure for Canada? There is also a wide variation

among the individual States as to public and private ownership. Maine, with 2,420 miles of coastline, has only three per cent in public ownership. This contrasts to the State of Oregon with 500 miles of coastline, 48 per cent of which is in public ownership. What is the corresponding situation in the Canadian coastal provinces.

2. The relationship among capability, ownership and use of coastal land. For example, what is the present land ownership and existing use of the land at those coastal areas with high capability for recreational use?

3. Non-resident ownership of coastal land. Is it a problem? Its extent? Social and economic effects on an area? How are different jurisdictions reacting to the issue?

4. The conflict between private demand and public interest. For example, how does one rationalize the competing demands between private cottagers and day-users for a stretch of coastal land?

5. Instruments for managing coastal land use. The effects of sales versus leasing of coastal land; role of easements, zoning and taxation in directing coastal land use?

CONCLUSION

The assemblage of information on coastal land ownership and provision of access to the shore are only reactions to needs. What is required in the long term is a program of land-use planning to assure the effective and efficient use of one of our most valuable natural resources - the coastline. This can only be accomplished if we have basic background information, such as land ownership, on which to base sound land-use planning.

In conclusion, it should be emphasized that any program aimed at coastal land management will involve increased land-use controls, whether these regulations are to protect coastal land from indiscriminate use or erosion, or to preserve public access to the shore. The absence of greater land-use controls to date has been due, in part, to the lack of public acceptance of the need for such controls. However, with the increased public concern expressed on the issue of environmental degradation, the acceptance of greater restrictions would not only seem to be more palatable, but necessary, if the coast is to continue to play the role it now does in providing enjoyment and recreation opportunities for large numbers of people.

POTENTIAL OF C.L.I. DATA AND GEOGRAPHIC INFORMATION SYSTEMS FOR A COASTAL PLANNING STUDY

M.J. Romaine and R.J. McCormack[1]

INTRODUCTION

A review of the past fifty years in Canadian history documents changes in sociological, technological and very recently environmental problems, concerns and emphasis. In brief, the 1920's were a decade of development and continued land settlement over much of Canada's frontier. The depression of the 1930's followed by World War II and the associated demands for and growth of urban-orientated industry markedly influenced the trends in land-use adjustment and population migration from a rural to an urban setting.

The post-war boom of the late 1940's and early 1950's increased the demands on the land for a variety of alternative uses. The launching of the first artificial satellites in the late 1950's probably made mankind aware of the rapid technological strides being made while at the same time underlined the existing social and economic problems still to be resolved.

The need for a land capability inventory therefore did not arise suddenly, but was the result of decades of intense technological and sociological change. The Senate of Canada, Special Committee on Land Use and the Resources for Tomorrow Conference of 1961 provided forums for the increased concensus of opinion supporting the idea of a national capability inventory. From 1962 to 1964 consultations between officials and resource specialists from the federal government, provincial governments as well as other public and private agencies resulted in the establishment of terms of reference, organizational form and financial, administrative and technical arrangements to carry out the Canada Land Inventory program.

OBJECTIVES, SCOPE AND ORGANIZATION OF THE C.L.I. PROGRAM

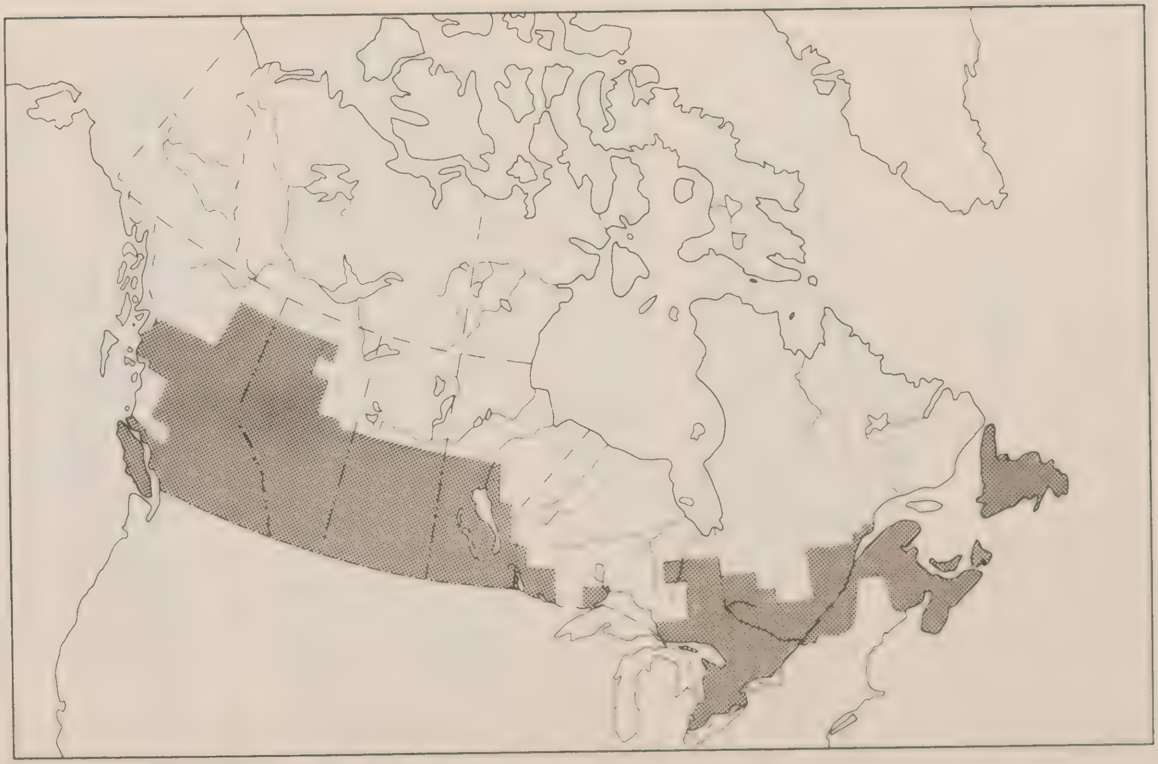
The broad objective of the Canada Land Inventory is to classify lands as to their capabilities, to obtain a firm estimate of the extent and location of each land class and to encourage use of the C.L.I. data in land use planning. This objective can be further broken down into the following three sub-objectives or program activities.

Activity Number 1 - To classify and map lands as to their capabilities and present land use.

The C.L.I. established a common base for data description and presentation and arranged for the generation of maps and related data covering present land use, and the capability of the land for agriculture, forestry, recreation, and wildlife-ungulates and waterfowl. In addition supplemental programs in sport fish capability and agroclimatology were implemented in some provinces.

[1]Lands Directorate, Department of the Environment, Ottawa

AREAS COVERED BY THE CANADA LAND INVENTORY



The classification systems rate land according to different criteria.[1] Agriculture includes the feasibility of mechanical cultivation and harvesting, forestry embraces the potential for the production of wood, recreation indicates the ability of the land to attract and sustain outdoor activities and wildlife indicates the ability of the land to support the production and migration of ungulates and waterfowl. The systems however are similar in the following respects.

1. All are seven class systems comparable in a relative but not necessarily in an absolute sense.

2. With the exception of the recreation sector, which details the positive features of the landscape, all systems list the limiting factors which downgrade land units from the highest capability.

3. All systems are national in character; thus a class assigned to an area in Newfoundland has the same meaning as a similar class in British Columbia.

4. All site factors are incorporated into the capability rating.

5. Only physical factors are assessed - not locational, economic or accessibility.

6. The systems are meant to serve as a basis for land use planning but not for land management.

The area being covered by the C.L.I. program represents approximately one million square miles including all of the Maritime Provinces as well as the Island of Newfoundland and the settled portions of Ontario, Quebec and the western provinces.[2]

With the exception of PLU in eastern Canada, undertaken on our behalf by the Geographical Branch and wildlife waterfowl completed by CWS, the provinces carry out the work within their own boundaries. Co-ordination is achieved by arrangement with federal government resource departments. Mapping is carried out at two scales; the 1:50,000 scale are utilized as the basic documents for planning are available only from the provinces and may be obtained from the provincial C.L.I. co-ordinators' office or provincial resource departments map libraries. The data are subsequently generalized to a scale of 1:250,000 and submitted to Ottawa for computer input and publication.[3]

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[1] R.J. McCormack and P.J.B. Duffy. The Canada Land Inventory with Emphasis on the Forestry Sector. Canada Land Inventory Department of Environment (Ottawa, Ontario, 1971) p. 5

[2] Department of Regional Economic Expansion. A Guide for Resource Planning, The Canada Land Inventory. (Ottawa, Ontario - Queen's Printer, 1970)

[3] Published C.L.I. maps are available upon request from the Lands Directorate, Department of the Environment and from the Map Distribution Office, Department of Energy, Mines and Resources. In addition, published maps can be purchased from Information Canada.

Activity Number 2 - To obtain a firm estimate of the extent and location of each land class.

The Canada Geographic Information System (C.G.I.S.) was set up to permit the input, reduction, storage, analysis and retrieval of the large quantities of data generated from the C.L.I. by an automated computer system. The system design and development started in 1963, implementation began in 1965 and is now reaching its final stages of development. The system consists of three main parts: The Input subsystem, the Map Reduction subsystem and the Retrieval subsystem.[4]

The C.L.I. maps as well as those showing administrative, watershed and shoreline boundaries are the prime source documents. From these documents the map faces and associated classification information are scribed, scanned and digitized for input. The information is then reduced to a form which will permit easy retrieval of detailed or general information relevant to economic, geographic and sociological studies of current land status and land potential. After reduction, the data bank may be used by the C.G.I.S. Retrieval subsystem which has been designed to analyse the C.L.I. Data Bank. For each separate area or face on the map, the data bank contains:

1. A unique identifying number.

2. The classification data from the map.

3. The calculated area.

4. The location of the centroid.

Maps of a similar type, for example all present land-use maps or all recreation maps are grouped together to form a coverage. Each coverage will eventually comprise all the mapped land in Canada.

Activity Number 3 - To encourage use of C.L.I. data in land-use planning.

In November 1967, the C.L.I. program was extended to cover pilot projects in land-use planning.[5] Under this program the federal government may underwrite the costs of one pilot-scale land-use planning study in each province.

It was realized that the maximum usefulness of the Inventory would be achieved only by developing and evaluating applications of the data in the planning process. The objective was to provide opportunities for assessing the adequacy of the data in development planning, and to familiarize those engaged in land-resource planning and management with the data.

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[4] Canada Geographic Information Systems, Lands Directorate, Department of Environment. Unpublished material describing the Canada Geographic Information System.

[5] Department of Regional Economic Expansion. The Canada Land Inventory Objectives, Scope and Organization. The Canada Land Inventory Report No. 1 (Ottawa, Ontario - Queen's Printer, 1970) p. 16-18.

To ensure maximum flexibility in the development of possible applications of the Inventory data, very few methodological specifications have been laid down for the projects. However, certain general conditions must be met before proposals for land-use planning studies are approved. These conditions have been established to ensure that a comprehensive view towards land use planning will be developed in the projects and to encourage the implementation of the land-use plans.

PRESENT STATUS AND USE OF C.L.I. INFORMATION

The C.L.I. program will be virtually completed by 1975. At present, fieldwork, mapping, and maps and reports are complete for the Atlantic provinces and Ontario; the three Prairie provinces and Quebec will be completed by the end of the 1972-73 fiscal year; British Columbia is expected to be finished by 1975.

The Geo-Information System is now operational; the data bank for the Maritime provinces will be completed by the end of April, 1972.

All provinces with the exception of Newfoundland and British Columbia have initiated pilot land-use projects. The province of British Columbia has elected, as an alternative, to carry out land capability analysis studies in conjunction with their ongoing Canada Land Inventory program. Pilot land-use studies have been completed for the Maritime provinces, virtually completed in Quebec and Ontario and scheduled for completion in the Prairie provinces by the end of 1972-73.

The primary value of the C.L.I. maps and data is in land-use planning projects and programs. The sector maps and reports provide planning and resource specialists with the first comprehensive view of the land. The overlay or land capability analysis process requires the development of assumptions and principles concerning the relative merits of use both within and between sectors. The end product is an indicative land-use map. The principles employed and the stage at which the land capability analysis is carried out during a planning study varies from region to region depending upon the area's characteristics and the objectives and goals of the study. To date, the land capability analyses are conducted manually by a mix of resource specialists. The C.G.I.S. has the capability to offer a technical alternative whereby different coverages can be combined and evaluated by a computer process. The limitations of the Geo-Information System to date have been: an incomplete data bank and the fact that the overlay or composite map process requires as prerequisites predetermined criteria for weighing, eliminating or presenting information in final map form.

Combined with political, social and economic information, the land capability analysis or composite map can serve as a basis for follow-up administration and management policies and programs.

Ideally, the land capability analysis would be conducted prior to major alienation, development or management programs. However, in partially developed areas or where land-use planning studies will not be completed in time, single sector resource capability maps serve as a basis for the location of follow-up surveys and research, the identification of areas as to certain preferred use or as guidelines for follow-up management plans and programs.[6]

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[6] R.J. McCormack, "Interim Report on Progress and Use - Canada Land Inventory". Department of Regional Economic Expansion. (Ottawa, Ontario, May 1970)

THE POTENTIAL USE OF THE C.L.I. DATA IN COASTAL PLANNING STUDIES

In the absence of precise knowledge of what the coastal zone study is intended to embrace one must make certain assumptions and indeed, generalizations to relate the C.L.I. data and processes to the study. Let us assume for discussion purposes that three distinct environments are involved. These are:

1. Marine
2. Terrestrial
3. Land - water interface

Each of these can be subdivided into sub-environments depending on the purpose for which an hierarchical system is required. While acknowledging the inter-relationships between these various environments it is easier for this purpose to consider them as discrete entities.

(1) Marine Environment

As the whole system and organization was lands oriented there is very little, if any, application of the C.L.I. data to the marine environment.

There is one potential problem which is worthy of noting. It relates to the two grid systems being developed, one for CAFIS, i.e. Canadian Atlantic Fish Information Service, the other for the Marine Sciences Division and their relationship to each other and to the grid system developed for the Geographic Information System. Without questioning the validity of these three systems I think it would be wise to ensure compatibility between these grid systems particularly as in any coastal zone study the various grid systems may come into conflict. Since all of these Divisions are now in the same department it makes good sense to ensure that they are at least comparable.

(2) Terrestrial Environment

It is in the lands or terrestrial milieu, including fresh water, that the C.L.I. system and data have the greatest potential. Excluding industrial and municipal pollution perhaps the greatest environmental degradation results from bad land use practices or improper land use. The former can include the whole range from clear cutting on easily erodable soils through improper agricultural cultivation practices to clearing and construction in slump susceptible soils. One could enumerate a long list of land use practices and improper land use which result in pollution in the broad sense. However it may be more useful to consider how this can be prevented.

The solution in the long term is to effect optimum land use through land use planning followed by land use controls. The Canada Land Inventory was designed to be the data base for land use planning and in a variety of projects in most provinces of Canada including all the Maritime provinces has been found to be valuable for this purpose. Land use controls which must be exercised by the provinces can, of course, be imposed in a variety of ways including regulations, purchase, zoning or easements or a combination of these. Whatever the means the C.L.I. maps, data and systems would be an indispensable part of the land-use planning process.

(3) Land - Water Interface Environment

This environment which might be characterized as the wet beach, dry beach, dune and lowland area to what might be termed the backshore upland is the area which might well become, if it is not already, the most valuable natural asset in the coastal zone. In fact the ownership of and access to these lands has become a highly emotional issue in the Maritime provinces. These lands have the inherent capability of becoming a great asset; on the other hand they can also become a major source of pollution if their ownership and development is not closely controlled.

Whatever means are employed to control the ownership and use of these lands, it is essential that each province begin to develop an overall plan for the management of this valuable resource. The Recreation Capability maps, already completed for the Maritime provinces identifies the capabilities and the possible outdoor activities associated with all of these lands and are an invaluable basis for developmental planning. It is a fact that the provinces have already utilized these data extensively for this purpose.

I have attempted, in a very general way, to outline the potential uses of the C.L.I. data and systems to the three major environments into which the coastal zone may be divided. Finally it might be useful to consider the application of the Geographic Information System to the whole coastal zone study. As indicated earlier all of the C.L.I. maps will be in the system by the end of April of this year. In effect the computerized data bank will enable retrieval both within and between sectors by any previously defined geographic area. While it is not necessary to enumerate the vast number of comparisons possible from this computerized data bank, the potential value of the system to a coastal zone study should not be overlooked.

The foregoing provides some insight into the areas where C.L.I. experience and expertise can be of assistance. Admittedly, the planning and management of land represents only part of your concern with coastal areas. However, if better planning and management of the coastal lands can be achieved, this will certainly assist in controlling those activities of man that have an undesirable impact on the adjacent coastal waters.

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